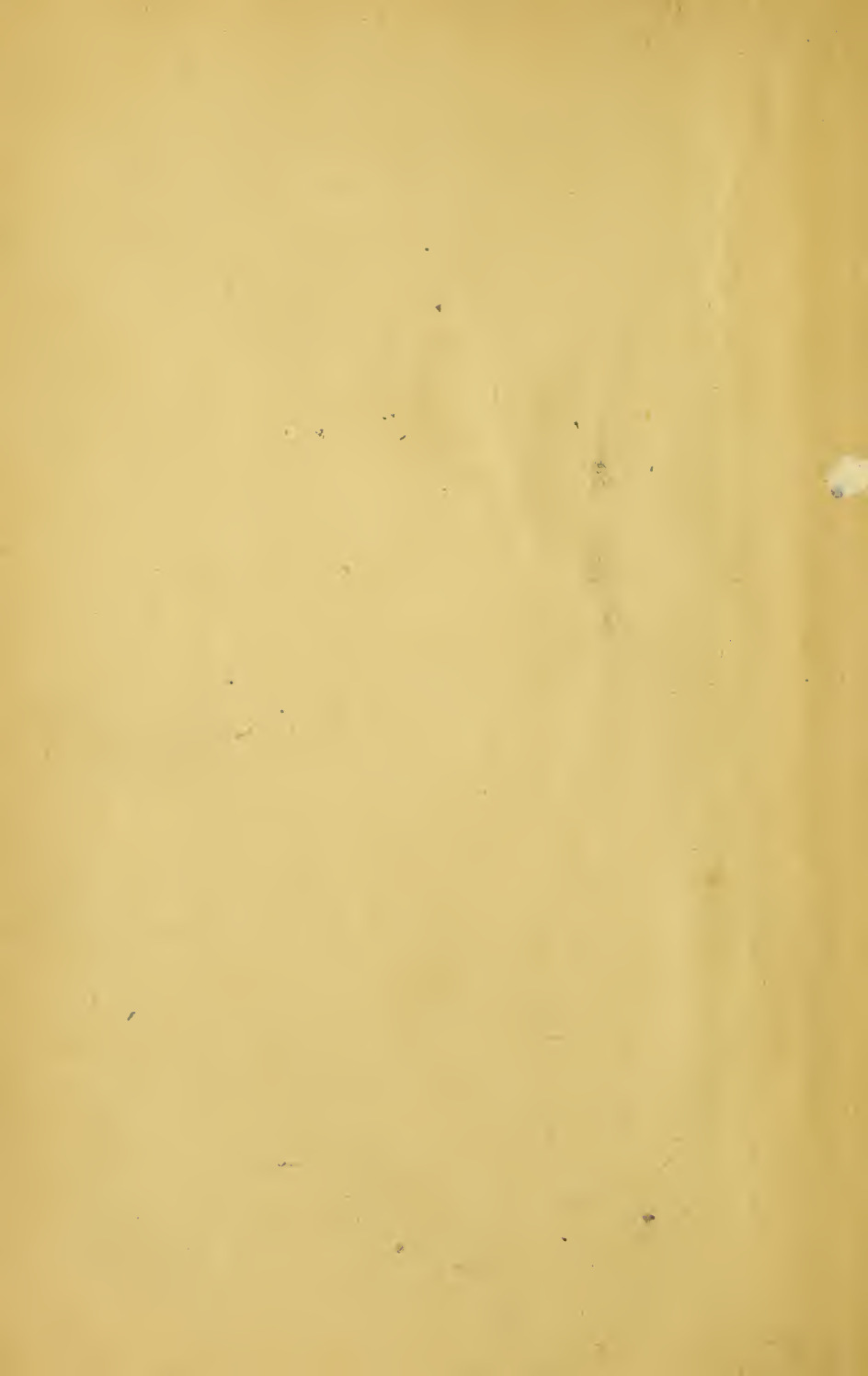


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DESCRIPTION
OF THE
BOSTON WATER WORKS.

ILLUSTRATED WITH FIVE LITHOGRAPHIC PLATES.

CHICAGO:

PUBLISHED AT THE OFFICE OF ENGINEERING NEWS.
1878.

E. C. Clarke
Aug. 26. 1873

PREFACE.

In the preparation of the following pages we are much indebted to the gentlemen connected with the Water Department, and the City Engineer's office, of the City of Boston, for their valuable assistance given to our Special Correspondent, who spent several weeks in that city collecting data for the description of the Works, and in preparing the drawings for the Plates accompanying the same. The work having been done under such favorable conditions we consider the best guarantee of the accuracy and reliability of the following description. The drawings were compiled by our Special Correspondent, Jno. W. Weston, C. E., and printed on stone direct therefrom; the Text and Plates were published in *ENGINEERING NEWS*, but are now only to be had in the present form.

CHICAGO, *May 31st, 1878.*

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BOSTON WATER WORKS.

LAKE COCHITUATE.

Lake Cochituate, formerly known as Long Pond, the main source from which the supply of water for the city of Boston is taken, may ^{be} considered a chain of natural, subsiding Reservoirs of water, three in number, having a general direction nearly north and south; its extreme length in a direct line being about three and one-half miles, and its greatest breadth about eighteen hundred feet.

Two county roads crossing it, divide it into three nearly equal parts, which for convenient reference, are designated as the Northern, Central and Southern Divisions.

The water gradually increases in depth from the shore, in each division; at high water, or when raised ten feet above the flume, or thirteen feet and thirty-six one-hundredths above the bottom of the Conduit; its greatest depth is about seventy-two feet in the Southern, fifty in the Centre, and sixty-four feet in the Northern Division. When the water is at this elevation, the superficial area of the Lake is estimated to be eight hundred acres.

At 3 ft. 5 in. above the bottom of the Conduit, the area of the Lake is 490 acres, and its capacity is 13,313,000 wine gallons; for every inch added to the above height up to 5 ft. there is an increase of one acre in area, and the total capacity is increased to 270,834,000 wine gallons; for every succeeding inch up to 7 ft. there is an increase of area of 3 acres, and the capacity is then 626,420,000 gallons; from 7 ft. to 10 ft. there is an average gain in area per inch of rise, of $2\frac{1}{2}$ acres, and the capacity is increased to 1,234,028,000 gallons; in the next 16 inches of rise there is a gain of 23 acres and a capacity increased to 1,527,132,000 gallons; for the following 24 inches there is an increase of area of 5 acres per inch of height and at 13 ft. 4 in., or high water mark, the total capacity of the Lake is 2,011,165,000 wine gallons and the area 801 acres.

The shore of the Lake is generally a bold sand and gravel bank, and the increase of surface which is produced by raising the water takes place mostly in a great meadow in the Southern Division, also on another meadow at the southerly end of the same Division; on some low grounds near the

northerly end of the Central Division, at the mouth of Snake brook; and lastly, in some small bays which occur in other places. When the water is raised eight feet above the flume, there are one-hundred and twenty-five acres not covered with more than five feet depth of water; at six and five-tenths feet above the flume, there are one hundred acres covered with a depth of water not exceeding five feet; at three feet above, the peat meadow in the Southern Division is to a great extent covered: but the other meadows in the same Division, and that in the Central, are mostly bare. The whole circuit of the Lake, including the meadows, is about sixteen miles; and excluding those, about twelve miles, measured at the verge of the Lake, when the water is eight feet above the flume.

The tract of country which drains into the Lake is bounded by the ranges of hills which divide the streams running into the Merrimack from those which run into Charles River, and, as surveyed, covers an area of 12,077 acres, including the Lake. Deducting from this amount 677 acres as the area of several ponds included in it, which are estimated to lose by evaporation from their surfaces a large proportion of the rain which falls upon them, there remain 11,400 acres or 496,584,000 square feet, as the watershed from which the Lake derives its supply.

The flume referred to in preceding paragraphs was known as "Knight's Flume," and was used by Mr. W. H. Knight, who owned the outlet of the Lake at the time of the passage of the Act, in utilizing its waters for manufacturing purposes. The floor of this flume was 3.36 ft. above the bottom of the Conduit; the waters of the Lake were at first raised to 8 ft. above the floor of the flume, but afterwards to 10 ft., the cost of the two last feet being \$27,130, which included the damages paid for submerged lands.

DAMS.

There are two Dams at the outlet, which is on the the west side of the Northern Division. The First is of solid masonry, of granite, and raised to a height sufficient to retain the water to a point ten feet above the floor of the flume. This corresponds with an elevation of 134.36 feet above tide marsh level; the floor of the flume being 124.36 feet above the same level.

The Second Dam is at a distance of about five hundred feet below the first, and is for the purpose of lessening the pressure upon the upper dam; it also is of solid masonry, with an overflow of twenty-three feet in width.

The Gate House at the Lake, is situated on the eastern side of the Northern Division opposite to the dam, and is built a sufficient distance into the Lake to admit the water from the necessary depth. The bottom of the Aqueduct, which here commences, is placed at an elevation of three and thirty-six one-hundredredths feet below the floor of the flume. When the Lake is raised to the high-water mark, it will stand thirteen and thirty-six one-hundredths feet above the bottom of the Conduit. (See plate No. 2).

In the house, there are four gates for regulating the admission of water into the Aqueduct. They are of cast-iron, with composition or gun-metal

facings, and a frame of the same materials, set in hammered stone ; and are worked by composition screws in composition nuts.

This building is twenty-nine feet six inches by thirty-nine feet six inches, of hammered granite, with a metal roof, secured effectually from intrusion. The floor is of granite, and there are two flights of granite steps from the floor down to the Conduit.

A stone culvert is also constructed beneath the road, which divides the Northern from the Central Division, in which provision has been made for placing stop planks, so that the water can be shut off from the Northern Division; and thereby about two-thirds of the water in the Lake can be retained, in case it should be necessary to repair the gate house or dams.

MARGINAL LANDS.

To enable the city to exercise a proper control over the waters of the Lake, and for the purpose of preventing any acts which might tend to impair their purity, as well as for regulating the right to overflow the adjoining lands, it was authorized by the Act to take and hold a strip of land, not exceeding five rods in width on the margin of the Lake, which strip the city now owns.

DUG OR MONSEMOG POND.

This pond, which was conveyed to the city, is South about 113 feet from the southern shore of the Lake, and separated from the peat meadow, on the Southern Division, by the county road; a culvert, two feet in diameter is laid beneath the road, by which the waters are discharged into the meadow, and thence pass into the Lake. It contains about forty-four and one-half acres. The shore all around is a steep gravelly bank, eight or ten feet high, and the pond naturally derives its waters wholly from springs. The city has also acquired a right to divert the waters of a brook on the east side into it, and thereby insure the filling up of the pond every winter.

The water is quite deep, and remarkably pure and soft, and forms a highly important tributary to the Lake.

High water mark in this Pond is seventeen feet above Knight's Flume; or one foot nine inches below the gate house floor, and one hundred and forty-one and thirty-six one-hundredths above tide marsh level.

The town of Natick now obtains a supply from this pond, so that its value to the city has been somewhat diminished.

DUDLEY POND.

The City also purchased the outlet to Dudley Pond, containing *one acre and thirty rods*, and took possession of its waters. This pond lies in a north-eastern direction from the Northern Division of the Lake, and contains eighty-one acres, at an elevation of about twelve feet above it. The water is very pure and soft, and there is no other outlet than that owned by the City, through which it flows into Sudbury River.

This pond was connected with the Lake in the year 1861, thirteen years after the introduction of the water into the City, by means of iron pipes eighteen inches in diameter and about eight hundred feet long, which pass under the road leading from Wayland to Newton: in making this connection, it was necessary to cut through an embankment sixty feet high, as the nature of the soil prevented its being tunnelled. The land between this pond and the City's land on the margin of the Lake was taken possession of under the Act, but was subsequently purchased.

High-water mark in this Pond is twenty-two feet and ten one-hundredths above Knight's Flume, or six inches below the top of the gate house floor, and one hundred and forty-six feet and forty-six one-hundredths above tide marsh level.

THE AQUEDUCT.

The Aqueduct, for convenience in its management, is divided into two divisions, the WESTERN and EASTERN. The Western extends from the Lake to and including the Receiving Reservoir in Brookline. The Eastern commences at the Brookline Reservoir, and comprises all the iron mains from Brookline to the City, and the Distribution in the City.

THE BRICK CONDUIT. — (See Plate No. 1.)

The course of the Brick Conduit is accommodated to the elevation of the different parts of the line, by winding in a series of irregular curves; care being taken, where it was possible, to adopt such a route as would permit its being buried entirely beneath the natural surface of the ground.

Its general direction after leaving the Lake is southeasterly for about four and one-half miles, to near the village of West Needham. It then turns and runs northeasterly about two miles. Thence easterly, crossing Charles River, about three and one-quarter miles. Thence northeasterly through the *long* Tunnel, about two and one-half miles to the Ventilator. Thence southeasterly about two and one-quarter miles, through the *short* Tunnel, to the Receiving Reservoir at Brookline; passing through parts of the towns of Wayland, Natick, Needham, Brookline and the city of Newton.

The Conduit, from the Lake to the left bank of Charles River, and from the right bank of the same to Brookline Reservoir, is built of brick masonry, eight inches thick, laid in hydraulic cement. It is, in section, an egg-shaped oval, the largest end down; the greatest width is five feet, and the extreme height six feet four inches in the interior. It is covered with a plastering of hydraulic cement on the outside, from the top down to the chord line of the lower or inverted arch, more effectually to prevent the percolation of surface water into it. It is supported on a puddled embankment, built up above the chord line of the inverted arch, in all cases where the Aqueduct passes over ground the level of which falls below the grade line, and also where the ground was found to be marshy, or from any cause not suffi-

ciently solid to support the superstructure. In the latter case, the mud and loose soil were previously removed until a firm bearing could be had. The whole is covered with an embankment eight feet wide on the top, with side slopes of two feet horizontal to one foot vertical, and raised four feet above the top of the Aqueduct. The Aqueduct through the whole distance thus rests upon, and is covered with earth to a depth of at least four feet, and it is nowhere raised, so as to admit a passage beneath it, excepting at the culverts,—at the crossing of Charles River, which it passes by three iron pipes, two of thirty inch, and one of thirty-six inch diameter,—and where it crosses the valley in Needham, near the west bank of the river. In the latter place, it is carried over the roadway by a granite bridge of one arch of twenty feet span, and fourteen feet high, and from there to the west pipe-chamber on a puddled embankment, in some places forty feet high.

The Conduit, from the Lake to the Brookline gate house, is divided into Three Divisions; the first being 29,800 feet in length; the second, 26,400 feet; and the third, 23,000 feet; and these divisions are subdivided into Sections; the first comprising sections 1, 2, 3, 4; the second, 5, 6, 7, 8, 9; the third, 10, 11, 12, 13, 14, 15.

The whole line is divided on the inside by stations of one hundred feet each, which are marked by metallic figures placed on the sides, about five feet above the bottom of the Conduit, and the large Plans of the Conduit being marked in like manner, makes it an easy matter to fix upon the exact locality above ground.

The Conduit, for the greater portion of its length, is laid entirely beneath the natural surface of the ground, appearing above only for short distances at irregular intervals. The greatest depth of any part is at the Tunnels in Newton and Brookline, at the former of which, the bottom is about eighty feet; and at the latter, about sixty feet below the surface.

The deepest excavations made for it were;—at a short distance from the Gate House at the Lake, near the waste weir at Dedman's Brook; near the waste weir in East Needham; and near the cold spring in Section nine, in Newton. It was laid at those places about thirty feet deep. The longest interval that it remains beneath the surface entirely is from its junction with the Lake, for a distance of about two and a half miles. The bottom of the Aqueduct is not raised above the level of the natural surface of the ground for more than three-fourths of a mile through its whole extent.

The rate of descent in the brick portion is three and one-sixth inches per mile. The Fall for the whole distance, including the Pipe Section over the valley of Charles River, is nearly three and one-half inches per mile.

The whole descent or fall is 3.74 feet in the brick Conduit, which is 14.307 miles long. In the Pipe Section, 1,095 feet long, it is 0.52 feet, making in the whole distance, 14.627 miles, a descent of 4.26 feet.

The whole quantity of land originally purchased and taken possession of by the City along the line of the Aqueduct, from the Lake to Brookline

Reservoir, was three hundred and five acres and eight rods; the City has the fee in two hundred and seventy-six acres and ninety-five rods; and holds, by possession, taken under the Act, twenty-eight acres and seventy-three rods.

There have been several small lots purchased since, and several acres have been sold.

The first brick of the Aqueduct was laid October 19th, 1846.

The bottom was all united September 17th, 1848, and Water let in October 12th, 1848.

THE MAINS OVER CHARLES RIVER, PIPE CHAMBERS AND CHARLES RIVER BRIDGE.

The remainder of this part of the Aqueduct comprises the Mains over the valley of Charles river and the Tunnels in Brookline and Newton. The former consist of three iron pipes, two of thirty inches in diameter, and one of forty inches, which descend 52.11 feet below the level of the Aqueduct on the west bank of the river, crossing on a stone bridge built over the river; and thence are continued over the intervalle at a rather low level, and then rise to the Aqueduct on the eastern side.

The Charles River Bridge is constructed of hammered granite, of three elliptical arches, of thirty feet span and seven and one-half feet rise, and twenty-one feet wide.

The Pipe Chambers, constructed at each end of the Mains, are of granite; the horizontal distance between them is 1,095 feet. The admission of water is regulated by stop-planks.

The bottom of the west pipe chamber is 119.04 feet above tide level.

The bottom of the east pipe chamber is 118.58 above tide level.

The water in the river at its lowest state is seventy-one feet below the bottom of the brick Conduit.

THE TUNNELS.

There are two Tunnels excavated through porphyritic rock, of extreme hardness, in the towns of Newton and Brookline respectively. The former is *twenty-four hundred and ten feet*, and the latter, *eleven hundred and fifty feet*, in length.

A course of concrete is laid in the Tunnels, of variable thickness, to form a bottom of uniform inclination, coinciding with the level of the Aqueduct. Those portions which showed signs of perishable rock were lined with brick masonry; and brick arches of extra thickness were turned over the water course at all the shafts which had been sunk during the progress of the excavation, for the purpose of supporting the filling of earth which was put into them.

In the Newton Tunnel, the shafts were commenced at the west end, about November 15th, 1846.

The first drift was commenced at the west end, December 30th, 1846.

The last drift was completed April 28th, 1848.

The brick lining was completed August 27th, 1858.

In the Brookline Tunnel, the shafts were commenced December 17th, 1846.

The first drift was commenced about January 30th, 1847.

The last drift was completed June 20th, 1848.

The brick lining was completed August 30th, 1848.

THE WASTE WEIRS.

There are four Waste Weirs constructed for the purpose of letting off the water, and also for ventilation. They are built entirely of stone, with iron doors and stone roofs; the walls being carried up to a sufficient height to form an inclosure over the works. The overfall or weir is of stone, through the breast of which, two gates are fixed to draw the water off when required. The gates and gate frames are of composition metal set in cut stone, the gates being worked by composition screws in composition nuts.

The First Waste Weir in Section No. 3, is eight by fourteen feet, and situated at Dedman's Brook, about three miles distant from the gate house at the Lake. The level of the ground, is such that this is the nearest point where the water could be discharged.

The Second is the same size, and situated at the end of Section No. 5; about one mile west of Charles River, in East Needham. The Third, also of the same size, is situated in Section No. 10, at the outlet of Baptist Pond, in Newton Centre, about three miles east of Charles River. And the fourth, which is nine feet by fifteen feet five inches, is situated in Section No. 13, in Brookline, about a mile from the Reservoir.

Complete ventilation has been secured along the whole line of the Conduit by these Waste Weirs and one Ventilator built expressly for the purpose.

VENTILATION AND MAN-HOLES,

The only Ventilator, strictly so called, on the Aqueduct, is placed near the easterly end of the Tunnel, in Newton. It is built of hammered granite, and is eight feet square at the base, diminishing as it rises therefrom to a height of fourteen feet six and three-quarters inches, and is surmounted by a coping. The passage inside is four feet, one and a quarter inches. A great benefit derived from it consists in the means which it affords of an entrance into the Aqueduct, for the purpose of cleansing and examining. Man-Holes are also placed along the aqueduct at distances of about a quarter of a mile apart, for the latter purpose. They are covered with stone slabs. A Plug-hole, twelve inches in diameter, is also made near the Ventilator, to let off the water from the Aqueduct when necessary.

CULVERTS AND DRAINS.

There are Ten Culverts and Thirteen Barrel Drains, for the purpose of draining off beneath the Aqueduct the water in its vicinity.

The Culverts are all of granite, with hammer-dressed joints, and laid in hydraulic cement. Their openings are from two to eight feet wide; the smallest being square in form, and the largest having upper and inverted arches.

The Barrel Drains have stone ends and brick centres, and are laid in hydraulic cement. They are from one and a half to two feet in diameter.

CHESTNUT-HILL RESERVOIR

is a natural basin at a distance of about five and one-half miles from the centre of the city, and within the present municipal limits. At the time of its construction the land was situated in the towns of Brighton and Newton. Beacon street, which ran directly across the valley, was turned from its course to allow the building of the reservoir. The spot is a beautiful one. There are hills around the basin, particularly on the westerly side, from which fine views may be had of its winding, graceful lines and its sparkling sheets of water. An artificial bank was required only on the lower side of the valley.

FORM.

The reservoir is built in two parts, separated by a water-tight dam. A gate-house in the centre allows of communication between the two basins. Both parts are of somewhat irregular form. Together they are $2\frac{1}{2}$ miles in circumference.

The land bought by the city for this reservoir amounted to $212\frac{1}{2}$ acres.

The combined capacity of both basins is 731,472,429 gallons.

The easterly and the larger of the two basins is called

THE BRADLEE BASIN.

When full, its water area is $87\frac{1}{2}$ acres.

Average depth of water, 20 feet.

Its capacity is 550,583,485 gallons.

On the easterly side of the reservoir, and on the highest part of the embankment, is the principal or effluent gate-house. It fronts on Beacon street.

THE LAWRENCE BASIN

has a water area of $37\frac{1}{2}$ acres, and a capacity of 180,888,944 gallons.

The distance around the centre of the path which surrounds the Lawrence basin is 6,183 feet, or 1.17 miles.

GRAVEL PATH.

There is a gravel path around both basins eight feet wide, with six feet of sodding on each side.

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There is a gravel path around both basins eight feet wide, with six feet of sodding on each side.

THE DRIVEWAY

proper extends only around the northerly side of the reservoir, though Beacon street completes the circuit, and forms a driveway all around both basins. Beginning at the entrance arch on Chestnut-Hill avenue, the driveway is some 30 feet above the surface of the water, but it gradually drops as it winds around, until by the time the Lawrence basin is reached the roadway is nearly on a level with the reservoir. Its length is 1.7 miles, and if Beacon street is included in the drive, the distance is two and one-half miles.

The width varies from 60 to 80 feet.

It is a macadamized road, kept in the best order. The scenery is pleasantly diversified, sometimes by glimpses of the beautiful deep blue water, and again by groves of trees and plots of green grass.

THE ARTIFICIAL DAM,

forming part of the Bradlee basin, is 2,000 feet in length. It is 20 feet wide on top, and in one place 150 feet wide at the base. The greatest height, near the effluent gate-house, is 35 feet. In the centre of this bank is a puddle wall 10 feet thick at the base and four feet at the top, founded on the rock. It is built of clay from the neighborhood of Cambridge, mixed with material found near the spot. There is a brick tooth wall in the centre, 18 inches square, laid on the rock, added as an additional precaution against leakage. The surface of the rock was very irregular. The earth of which the main part of the dam was built was put on in layers and well watered and rolled.

THE STONE LINING.

of the reservoir is built of dry rubble masonry $2\frac{1}{2}$ feet thick. It is laid on the water side to protect the banks from wash, and is capped with granite blocks whose top is 3 feet $4\frac{1}{4}$ inches below the top of the walk. It extends $19\frac{1}{2}$ feet measured on the slope, or $8\frac{1}{2}$ feet measured vertically. Then there is a berme of 5 feet, and from here a stone rip-rap covers the slope, "three to one," into the reservoir.

THE EFFLUENT GATE-HOUSE.

already referred to, is the most important structure on the reservoir grounds. A bed of quicksand, 28 feet in depth, rendered the laying of the foundations a difficult task. Rubble piers with brick arches rest on the bed rock and support the structure. These were leveled off on top with a layer of concrete, and a heavy bulkhead, side walls, brick piers and groined arches complete the remainder of the substructure. On the water side of the bulkhead are four separate compartments for four lines of 48-inch pipes. Each compartment has places for a double set of stop-planks, a revolving screen, sluice-gates, and an open well in front of the pipe. The superstructure is built of

hammered granite. Outside of the bulkhead are stopcocks placed in the pipes. The wing walls on the water side are not founded directly on the rock, but are placed on piles.

Branch walls are built into the bank 80 feet long on one side, 25 feet on the other. Their section consists of four feet of rubble wall laid in cement, and 2 feet of brick work.

Outside of this gate-house is a brick chamber underground, which contains two gates. These control two lines of drain-pipes, which run through the embankment on arches. They connect with each basin, so that either can be drawn to its lowest level for cleaning or repairs.

Two hydraulic sluice-gates worked by a hydrostatic press were placed in position during the winter of 1873-74 in this gate-house. They are to shut off or let on the water to the 48-inch main. The need of gates at this point, that can be quickly operated, has been felt ever since the reservoir was first used and provision had been made for them when the gate-house was constructed. They have been designed with special reference to easy and rapid movement. One man can fully open either of them in less than four minutes, and they close by their own weight in less than twenty seconds, settling to their seats quietly. The openings are 48 inches square. The movement is vertical. When in motion the gates are carried on three pairs of wheels, 12 inches in diameter. The seats are not exactly parallel to the gate-frame, being inclined slightly from the vertical, so that when the gate is closed, the gate face and seat are in contact, and the wheels are lifted a fraction of an inch from their tracks. Vertically over each gate is a cylinder fitted with a piston 8-inch diameter and 4-feet stroke. The gates are held in any position by a friction clutch. The height of water in the reservoir is recorded by a float-gauge.

THE INTERMEDIATE GATE-HOUSE,

built in the centre of the dam separating the two basins, is also located directly over the aqueduct, which runs lengthwise through the dam and continues to Brookline reservoir. Four gates, one towards each basin and one on each end of the aqueduct, allow of turning the water any or all ways. Besides these there are two lower level gates connecting the two basins. There is also in one corner of this gate-house, a gate communicating with a line of drain-pipe laid through the Bradlee basin. The superstructure is of hammered granite, corresponding with the rest of the work.

THE INFLUENT GATE-HOUSE,

at the Lawrence basin, is the smallest of the three structures. It covers one gate that controls a connection between the aqueduct (which curves around one side of this part of the reservoir) and the basin.

A short piece of brick aqueduct, 4 feet by 4 feet 4 inches, connects the two. In the rear of the gate-house at one side of the driveway, and directly over the aqueduct, provision has been made for inserting stop-planks.

THE SEWER,

built to carry off the drainage of the valley, in order to keep it from entering the reservoir, is of brick work. Its total length is 7,980 feet, and there were employed in its construction 1,367,000 bricks and 4,300 barrels of cement. It commences on the northerly side of the Lawrence basin, and extends entirely around the westerly, southerly and easterly sides, continuing a short distance beyond the junction of Beacon street and Brighton street. It is of the following sizes:—

283	feet of 6 feet by 6 feet 4 inches.
482	" " 4 feet 8 inches by 5 feet.
1,820	" " 4 feet by 4 feet 4 inches.
1,803	" " 3 feet 4 inches by 3 feet 8 inches.
1,561	" " 3 feet by 3 feet 4 inches.
1,200	" " 2 feet 6 inches by 3 feet.
605	" " 2 feet 6 inches, barrel.
154	" " 2 feet, barrel.
60	" " 3 feet by 1 foot 6 inches, rectangular.
12	" " 4 feet by 4 feet 4 inches, rectangular.

Total, 7,980 feet.

From the terminus of the brick sewer, the system is completed to the entrance arch of the driveway with Scotch drain-pipes, varying from 16 inches to 6 inches in diameter.

Where the sewer passes directly under the aqueduct, the excavation was in solid rock, requiring great care in blasting. The entire trench was afterwards filled for 50 feet in length with concrete, built up to the height of the top of the invert of the aqueduct.

A considerable length of this sewer is from 15 to 20 feet below the natural surface, and a portion was built through solid rock.

THE 48-INCH MAIN.

From the effluent gate-house a 48-inch main is carried around Fisher hill to connect with the pipes which supply the city from Brookline reservoir, so that in case of any accident to that reservoir, the city can be supplied from Chestnut Hill.

The length of the 48-inch pipe is about one mile and a quarter. Its thickness is $1\frac{1}{4}$ inches. A blow-off was placed in a culvert near Beacon street, and there is an air-cock at the Goddard summit. There are four gates at the junction of this pipe with the other mains; three, a 40-inch, a 36-inch, and a 30-inch connection, are together in one underground chamber; and a 48-inch gate on the main itself, which was put in, April, 1875, is a little back and separated from the chamber.

Any one wishing to look more into the details of this reservoir is referred to the Annual Reports of the Water Board, and to City Documents Nos. 15, 27 and 73, of 1868; No. 59, of 1869, and No. 65, of 1870.

BROOKLINE RECEIVING RESERVOIR.

The Brookline Receiving Reservoir is situated at the Eastern termination of the brick portion of the Cochituate Aqueduct, in Brookline.

It is formed out of a natural basin, enclosed almost entirely by banks rising to a considerable height above it. On the northerly side, however, there was no bank; consequently a puddled embankment was built up to a height of about twenty-six feet, and was supported by a retaining wall eight feet in height. For the purpose of protecting the banks from the action of the water, the inner slope of the Reservoir is lined with a slope-wall of granite rubble, eighteen inches thick, and fourteen feet broad; this lining rising to within one foot of the top of the bank.

The greatest depth of water is near the principal gate-house, twenty-four feet. The least depth is near the upper gate-house, where it is about fourteen feet. The embankment is twenty feet wide at the top, with a gravel walk all around.

The area of the Reservoir, at a level of six feet below the top of the dam, is 22.31 acres, and its capacity 89,909,730 wine gallons; the contour of the water line being 4,696 feet long. At two feet below the top of the dam, it contains an area of 22.95 acres, and the capacity is 119,583,960 gallons; the contour of the water line is, at this level, 4,757 feet. The Reservoir in shape is an irregular oval.

A cylindrical brick Conduit is laid at a depth of eight feet within the northern embankment, to connect with that from the Lake, and conduct the water around the Reservoir to the Pipe Chambers, by means of which it was intended that the supply of the mains should be kept up, when the water is shut off from the Reservoir for cleansing it or for any other purpose. This answered the purpose for the first few years; but afterward the consumption increased so much, that it became wholly inadequate.

There are two Fire-Proof Gate Houses, the upper for receiving the termination of the brick portion of the Aqueduct, and the lower for the commencement of the iron Main leading to the City, with regulating gates, guages, etc.

The Principal or lower Gate House has its front on the street, where it is twenty-six feet, four inches wide, by thirty-six feet, eight inches high, including the basement, which is 16 feet, four inches. It is set in the embankment and projects about four feet in front of the retaining wall. The height in the rear is twenty feet. The length of the building is forty-four feet, four inches. Two iron stair-cases ascend from the basement to the main floor.

The building is of hammered granite with an iron roof. The main floor, is on a level with the top of the embankment, and the bottom of the gates which regulate the admission of water into the Pipe Chambers is twenty-six feet below the floor.

The gates and gate frames are of iron, plated with composition metal,

set in hammered granite. They are worked by composition screws in composition nuts. There are three pipe chambers, into which the mains now laid are introduced; two only having been used until the year 1859, when the 40-inch main was laid over the Mill-dam.

At the Upper Gate House is the termination of the brick Aqueduct, and it is fitted with Stop Planks and a Flap Gate for regulating the flow of water into the Reservoir. The building is of granite, with a stone roof. The front is eleven feet, three inches wide, by eleven feet, four inches high, and the length twelve feet.

The top of the dam or embankment is 126.60 above tide marsh level.

The upper floor of the principal gate house 126.76 " " "

Low water mark, 120.60 " " "

The bottom of the interior of the Aqueduct 116.76 " " "

The bottom of the Reservoir, 100.60 " " "

DISTRIBUTING RESERVOIRS.

There were three Distributing Reservoirs constructed for the purpose of receiving the water from the Mains leading from the Bookline Reservoir during the latter part of the day and the night, when it was presumed but little would be drawn from the Service-pipes; and of supplying it to the Service-pipes in the morning, when the greater portion for domestic purposes was required, by which means, a continuous supply could be kept up to a more uniform height.

These Distributing Reservoirs were the Beacon Hill, South Boston and East Boston.

It is now contemplated to remove or dismantle Beacon Hill Reservoir, and use the site for other purposes. It has not been in use since June 6, 1870; the High service works at Roxbury supplying its object and the neighborhood for which it was especially constructed.

The High Service works at Roxbury, has rendered the South Boston Reservoir useless, and water has been shut off since July, 15, 1872, but nothing has as yet been done regarding its ultimate disposal.

East Boston being now supplied from the Mystic Department, the Reservoir is shut off, but kept full of water in case of emergency.

THE MAINS AND DISTRIBUTION.

The city of Boston is supplied from its distributing reservoirs by three iron mains, 36 in., 30 in. and 40 in. in diameter,—the two former were the first in use, the latter was laid in 1859,—all starting from the effluent gate-house of Brookline reservoir.

When the gate-house was built, an extra 30 in. outlet was provided, and it being considered unsafe to remove it to substitute a 40 in., the 40 in. main is connected with it, and on the taper connection there is a 20 in. inlet, now capped, which can be continued through the masonry bulkhead above

the 30 in., if the supply be insufficient. Stop-cocks are attached to the mains just outside the gate-house. After leaving the gate-house they pass into Boylston street, in an easterly direction to the city. The 30 in. is on the north; south of this comes the 36 in., then the 40 in. A few hundred feet from the gate-house, these mains connect with a 48 in. pipe leading from Chestnut-Hill reservoir.

In a chamber near the road are three gates, each of which by means of branches connects the 48 in. pipe with one of the above mains, so that the supply from Chestnut-Hill may be cut off or let on as required from either of the mains. This connection prevents the head being suddenly drawn down in the distributing reservoir by an unexpected draught on the mains. A 48 in. gate, the largest on the works, to shut off water from the 48 in. main, is situated a little further back, and was put in in 1874. Between Brookline reservoir and these connections, there is a gate on the 30 in. pipe, to allow of the emptying of Brookline reservoir without interfering with the supply from Chestnut-Hill.

The three mains continue through Boylston street, Brookline, to the corner of Brookline avenue.

At the corner of Brookline avenue the 40 in. pipe passes under the other two, continuing along the avenue, the Mill-dam, Beacon street, crossing Charles street, and passing under the entrance on to Boston Common to the corner of Boylston and Tremont streets. On Boston Common the three mains connect.

The following supplies are taken from the 40 in. pipe on the route above mentioned:

On the Common, a 12 in. pipe runs to the Frog-pond.

At Longwood avenue, two 12 in. pipes supply Longwood.

At the junction of Brighton avenue and the Mill-dam, a 12 in. pipe takes into Brighton.

At Exeter street, a 16 in. pipe connects, and also a 12 in. on Beacon street.

At Arlington street, a 12 in. pipe supplies Arlington street; at Charles street, a 16 in. passes through Charles, reducing in time to 12 in., and ultimately connecting with the 30 in. Beacon Hill main. A 12 in. pipe leaves the above 12 in., passing through two prominent thoroughfares.

Returning to the corner of Brookline avenue, we may mention that three gates control the mains at that point. From the corner of Brookline avenue the 36 in. and 30 in. pipes continue along Tremont street, passing under the Boston and Providence R. R. near the Roxbury station. There a 24 in. takes off for the supply of the Roxbury and Dorchester districts, and the higher service of the city. This will be further noticed. At Dover street, three miles and two-thirds from the reservoir, the 36 in. is reduced to 30 inches, and at that place a 20 in. main is taken from the 36 in. to supply South Boston. Two gates are fixed here on the 36 in. main. The two 30 in. mains now continue through Tremont street to Boylston, crossing the Boston and

Albany R. R. on a plate-iron bridge. From this point the original 30 in. branches off into the Common towards Beacon Hill, and the other joins the 40 in. main, as already described.

A 30 in. branch passes down Boylston street to Washington street, where it reduces to 24 in., and running north supplies the northern part of the city proper, joining the 30 in. from Beacon Hill in Bowdoin square. At Haymarket square, a 20 in. pipe takes off the 24 in. and goes to East Boston.

From the 36 in. main nearly all the distribution connections are made. The 30 in. was used for high service, after its introduction, until the 20 in. high service pipe was laid in 1874; before the introduction of high service it was used to supply Beacon Hill; it, consequently, has few connections and those only at important points.

On the 36 in. main there are, besides what have been noted, two 16 in. and some nine 12 in. connections, besides the necessary gates and "blow-offs."

After arriving at Boylston street, the 30 in. main turns into the Common, connecting with the 40 in. low service and the 16 in. high service, so that in case of accident to the high service west of this point, the 30 in. can be used as such.

A 16 in. pipe leaves the 40 in. at Boylston and Tremont streets, running northerly, and reducing to 12 in. connects with the large main in Bowdoin square.

On the 24 in. stated as passing along Washington street, there are three 20 in., three 15 in. and eleven 12 in. branches, connected with which are the systems of smaller pipe to supply the several neighborhoods.

BEACON HILL HIGH SERVICE.

The Beacon Hill district, comprising about 48 acres, and which necessitated a high service supply, is furnished by a 20 in. main taking off the 24 in. main from Parker Hill reservoir. At Berkeley street the 20 in. pipe reduces to 16 in. in diameter, and continues across the Common to Beacon Hill. This main was laid in 1874. Before the 20 in. main was laid the supply was afforded by the 30 in. main already mentioned, which was used entirely for that purpose.

SOUTH BOSTON LOW SERVICE.

This service is supplied by two 20 in. pipes. One of these, taking off from the 36 in. main, crosses the Fort Point channel at the Dover street bridge; the draw is passed by a siphon, the distance between the arms of which is 41 feet. A trench was excavated into the hard bottom of the channel, 32½ feet below the top of the bridge, and the siphon was laid in a box filled in with hydraulic cement. This main in its route also crosses the Old Colony and the New York and New England railways, and runs to the reservoir on Telegraph Hill. The second 20 in. main leaves a 24 in. in Dorchester and passes to the reservoir on Telegraph Hill, crossing, *en route*, the Old Colony R. R. The two mains connect at the corner of Atlantic and Thomas streets.

The reservoir is not now used, as previously stated.

SOUTH BOSTON HIGH SERVICE.

This service is fed by a 12 in. pipe leaving the 20 in. high service pipe in Boston proper at Berkeley street, and connects with the South Boston high service pipes opposite the reservoir. This pipe crosses the Fort Point channel at Dover street bridge, with an inverted siphon. The siphon is made of 16 in. pipe, and is laid in a box surrounded by concrete.

EAST BOSTON.

This district is supplied by a 20 in. main which leaves the 24 in., in Boston proper, in Haymarket square. On its route to East Boston it crosses Charles river, over the Warren bridge, passing the draw by an inverted siphon, having a dip of 36 feet and a distance between the arms of 39 feet. It continues through Charlestown, where it has two connections with the Mystic works, and crosses to Chelsea over Chelsea bridge, where it passes under two draws. At the southerly draw the siphon dips 34 feet with a length of 50 feet; at the northerly draw the dip is 42 feet 5 in. and the distance between the arms 50 feet. All the siphons are enclosed in wooden boxes and protected with concrete.

In Chelsea this main has two connections with the Mystic works.

From Chelsea it passes to East Boston across Chelsea creek to Brooks street. The creek is crossed by means of flexible jointed pipe, 461 feet long. The flexible portion of the pipe was laid in a trench, dredged to about six feet in depth, and covered with clay and gravel to protect it. The creek itself is about 1,600 feet wide. The flexible joints were movable only in a vertical plane, and were adopted by Mr. Wm. S. Whitwell, the engineer.

In August, 1870, a leak occurred in this pipe. In 1871, a new main, 24 in. in diameter, was laid across the creek, and connected at each end with the 20 in. main; the old leak was then repaired. The new main was laid with a ball and socket joint, movable only in a vertical plane.

From Chelsea creek the main passes on to the reservoir, whence the distribution takes place through a 16 in. pipe, from which 12 in. pipes lead away into the principal thoroughfares. The supply main, 20 in., has a connection with the distribution independent of the reservoir; 6 in. pipes are used in nearly all the other streets not supplied with 12 in. mains.

DEER ISLAND.

An island in Boston harbor upon which the city reformatory institutions are located, is supplied from the East Boston mains by a 10 in., reducing to an 8 in. pipe, crossing Shirley Gut by two 8 in. flexible jointed lengths of pipe. The two lines were laid as a precaution, so that one could be used if accident happened to the other. The flexible joints are of the patent of John F. Ward, of Jersey City, and were put together on shore and hauled into place by a cable and windlass on Deer Island. The distribution on Deer Island is through 8 in. pipe; 4 in. is used only for "blow offs."

ROXBURY LOW SERVICE.

This service is principally supplied from the 24 in. Dorchester main, leaving the 30 in. and 36 in. near the Boston and Providence R. R. crossing. One 12 in. branch leaves the 24 in., also near the crossing, and passes through Roxbury by the side of the 24 in. on its way to Dorchester; and the 12 in. branch from the same point crosses the railway and passes up Tremont street by the side of the large mains. These two 12 in. mains have 12 in. connections at various points, one of them again connecting with the 24 in. It is useless to follow the ramifications of the system through Roxbury; occasionally the mains become connected with the other services, thus preventing isolation of any particular district—12 in. pipes are laid throughout the principal streets in this part of the city. West Roxbury is served by mains in connection with Roxbury proper as above.

ROXBURY HIGH SERVICE.

The pumping engines on Elmwood street take their supply through a 16 in. connection with the 24 in. main in Roxbury street. A 16 in. force main through Elmwood, Gardner and Centre streets and Fort avenue leads to the stand-pipe. From this 16 in. a 24 in. pipe branches off at Centre street to Parker Hill reservoir; from this at the junction of New Heath and Pyncheon streets a 20 in. main for the high-service of Beacon Hill and South Boston takes off, from which, when near the engine-house, a connection is taken to the pumps, securing thereby another force-main. Near the reservoir a 16 in. pipe passes away in a southwesterly direction for the high service of West Roxbury. The high service distribution is extended by 16 in. and 12 in. mains connecting with smaller pipes throughout the district.

DORCHESTER HIGH SERVICE.

Dorchester receives its supply from a 16 in. main leading from the stand-pipe, reducing to 12 in., at which size the mains extend.

DORCHESTER LOW SERVICE.

This supply is derived from the 24 in. main, before mentioned as passing through Roxbury, terminating at Dorchester avenue. The principal mains throughout this locality are 12 in. and 6 in., the 12 in. traversing the main streets.

BRIGHTON LOW SERVICE

is supplied by a 16 in. main connecting with the 40 in. pipe on Beacon street. This pipe crosses the Boston and Albany R. R. in Brighton avenue, by means of an iron bridge of two continuous plate girders, each 137½ feet long.

The principal mains are 12 in., reducing to 8 in. and 6 in., and traversing the district where required.

BRIGHTON HIGH SERVICE.

The high service is temporarily supplied by means of two small pumps and a reservoir, drawing their supply from a low service 12 in. pipe in Brighton. The force mains are 12 in. and 8 in. in diameter, and the supply mains are 12 in. and 6 in. in diameter.

The main lines of pipe can be traced on the maps of the Boston Water Supply, Plate 1; but the scale precludes the possibility of showing the network of pipes belonging to so extended a system of water works; nor, indeed, would such a map be of any considerable service, for, in the inception of so large a scheme, whatever is designed or contemplated is framed on the basis of possible requirements and contingencies, any deviation from which, after its completion, necessitates again adapting the existing means to the modified end. Such a map will therefore present innumerable flaws in arrangement, which might have been obviated if the necessities of the case could have been anticipated.

DETAILS.

We now come to the length of the various pipes comprised in the distributed system of the city of Boston, together with particulars concerning the appurtenances thereto.

The report for the year ending April 30th, 1877, gives the total mileage of pipes in Boston, to be 341 miles 4,800 feet of all sizes, and valves or stop-cocks at 3,652 in number. Besides this there were in all 3,874 hydrants of various descriptions, 1,082 meters, and 42,474 services.

The yearly report for 1877-78 not being yet published it is impossible to give details of that year's additions, more than to say that about 11 miles of pipe were laid with the necessary adjuncts. But returning to the year 1876-77, the statement shows that 115,369 feet of pipe were laid, with 213 stop-cocks; analyzed this gives 120 ft.—48 in., 1027 ft.—16 in., 47,503 ft.—12 in., 22,789 ft.—8 in., 42,322 ft.—6 in., 1,608 ft.—4 in.; there are represented in the total number of stop-cocks, 3—20 in., 2—16 in., 53—12 in., 23—8 in., 116—6 in., and 16—4 in. Of hydrants 252 were established and 15 abandoned. There were 1,149 new services run of a total length of 30,888 feet, averaging close upon 27 feet each, in length.

Before proceeding further, it would be as well to define the limits of Boston as governing the quantities detailed above, and the further details connected with this portion of the subject.

Boston, in the above regard, comprises the following districts or localities: Boston proper, Brookline, South Boston, East Boston, Roxbury, Dorchester, West Roxbury, Brighton and such portions of Newton and Needham as contain pipe connected with the Boston Works.

Exclusive of the above, and belonging to the Mystic Department, but under the control of the Boston Water Board, are Somerville, Medford, Charlestown, Chelsea and Everett. These will be treated of in the space devoted to the Mystic Department.

PIPE.

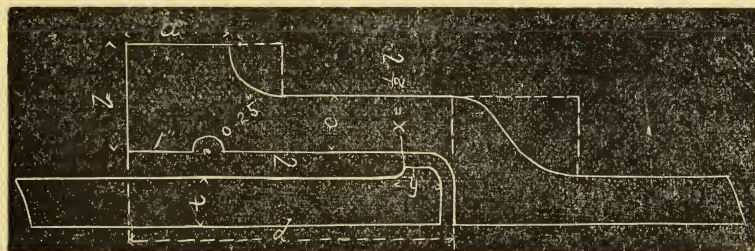
The pipe used by the Boston Water Works is of cast iron "of such a character as to make a pipe strong, tough, and of even grain, that will satisfactorily admit of drilling and cutting, and shall possess a tensile strength of at least 16,000 lbs. per square inch."

The pipes are coated with coal-pitch varnish applied according to Dr. Angus Smith's process. Both the pipe, before immersion, and the bath are heated to 300 deg. Fahr., and the casting is allowed to remain immersed for 30 minutes.

All pipes are tested by water pressure to 300 lbs per square inch.

WEIGHTS AND DIMENSIONS OF CAST IRON WATER PIPES.
BOSTON WATER WORKS.

DIAM- ETER. INCHES.	CLASS.	DIMENSIONS IN INCHES.						TOTAL LENGTH.		TOTAL WEIGHT OF PIPES.	WT. PER RUNNING FOOT LAID
		a	b	c	d	t	l	ft.	ins.	lbs.	lbs.
4	B	1.50	1.30	0.65	4.0	0.45	0.40	12	4	260	21.7
6	B	1.50	1.40	0.70	4.0	0.50	0.40	12	4	418	34.8
8	B	1.50	1.50	0.75	4.0	0.55	0.40	12	4	601	50.1
10	B	1.50	1.60	0.80	4.5	0.60	0.40	12	4½	815	67.9
12	A	1.50	1.60	0.80	4.5	0.58	0.40	12	4½	935	77.9
12	B	1.50	1.70	0.85	4.5	0.65	0.40	12	4½	1050	87.5
16	A	1.75	1.70	0.85	5.0	0.66	0.50	12	5	1413	117.7
16	B	1.75	1.90	0.95	5.0	0.75	0.50	12	5	1615	134.6
20	A	1.75	1.90	0.95	5.0	0.73	0.50	12	5	1945	162.1
20	B	1.75	1.90	0.95	5.0	0.85	0.50	12	5	2252	187.7
24	A	2.00	2.10	1.05	5.0	0.81	0.50	12	5	2588	215.7
24	B	2.00	2.10	1.05	5.0	0.94	0.50	12	5	2985	248.8
30	A	2.00	2.30	1.15	5.0	0.93	0.50	12	5	3690	307.5
30	B	2.00	2.30	1.15	5.0	1.10	0.50	12	5	4336	361.3
36	A	2.00	2.50	1.25	5.0	1.04	0.50	12	5	4929	410.7
36	B	2.00	2.50	1.25	5.0	1.25	0.50	12	5	5882	490.2
40	A	2.00	2.70	1.35	5.0	1.12	0.50	12	5	5897	491.4
40	B	2.00	2.70	1.35	5.0	1.35	0.50	12	5	7055	587.9
48		2.00	2.70	1.35	4.0	1.00	0.50	12	4	6266	522.1
48		2.00	3.00	1.50	5.5	1.25	0.50	12	5½	7917	659.7
60		2.25	3.40	1.70	6.0	1.375	0.50	12	6	10959	913.2



y = for 4", 6" and 8" pipes 0.6 inch
 " 10" and 12" " 0.8 "
 " larger sizes " 0.85 "

The weight of iron taken at .2604 lbs. per cubic inch.

In the above table, two classes are tabulated, A and B; class A, the lighter pipe, used generally where there may be the least head, while class B is laid usually in the lower levels of high service districts.

Special castings are made always under the conditions represented by class B.

The formula used in the calculations for the thickness of the pipes laid in the Boston Water Works system, is one completed and adopted by the City Engineer, Mr. Jos. P. Davis, C. E., and is as follows:

$$t = 0.0048 nd + 0.35$$

where t = thickness of pipe
 d = diameter of pipe in inches
 n = head in feet $\div 33$.

LOSS OF HEAD.

The maximum loss of head between Brookline Reservoir and the city is about 25 feet, which only occurs in sudden changes to very cold weather, and is due to waste, from the service pipes, to prevent freezing.

VALVES OR STOP-COCKS.

Some variety exists, and it would be a wonder if it were not so, in the gates used on this extensive system; but the old patterns are fast being superseded and new varieties—pre-eminently Bostonian, considering the Water Works officials design and construct them for their own use—are being continually added. The Boston Machine Co. manufacture most of the large stop-cocks, and a great number of their smaller ones still do service; but under the management of Mr. E. R. Jones, Supt. of the Eastern Division, a patentee of some useful inventions in Water Works fittings, improvement is constantly taking place. From the old gate with rectangular trunk, an advance was made to the spherical spindle chamber of the Boston Machine Co.; and gates somewhat similar to their pattern have been in use a long time; but now there is a prospect of a radical change in the construction of gates, reducing the weight and cost of manufacture very largely. Briefly it is this: the body with its pipe sockets is cast in one piece, the two valve seatings are inserted from the top, the upper portion of the spindle or valve and upper fixings are then connected, the gate shut down tight and the seatings leaded in from the pipe sockets. A tight and light valve is the result, and our own judgment can testify to the apparent solidity of the leaded points. The patentee of this invention is Mr. Marshall Burnett, foreman of the machine shops, Boston Water Works.

HYDRANTS.

A most important feature in water works distribution is the hydrant; the service it is called upon to render, being barely second in the consideration from which a water works system springs.

What was said of the stop-cocks may be quoted again for hydrants, a

steady improvement being visible in their construction. There have been used in Boston, since the regular introduction of water, many kinds, among which might be mentioned the Lowell, Ballardvale, Wilmarth, now known as the Boston, Kingston and Hooper. More recently the Lowry has deservedly come into most repute, and the many modifications in the fittings of hydrants generally, not excluding the Lowry, which are made in Boston by the Water Works Department, will ultimately, as with the valves, produce hydrants of a purely Boston type.

The hydrants used to-day are comprised under the three heads of Lowry, Boston and Post, and the majority in use are flush hydrants. The old-fashioned patterns developed a sad defect in their small barrels, and consequently, limited delivery. The Lowry overcame this, and in its being adapted for attachment directly to the mains, gave it a prominent advantage. The Boston Machine Co. manufacture these latter. One disadvantage connected with the Lowry was the large valve opening downwards against a heavy pressure of water. This was overcome in those already set, which when removed for repairs or otherwise, were fitted with a smaller relief valve, which is patented, which opened first, admitting water to the barrel and so reducing the pressure. The new ones are constructed with 7 in. valves.

An improvement has been effected in the matter of setting or removing Post hydrants, by an attachment consisting of a horizontal toothed quadrant gate worked by a pinion which thereby can be closed, shutting off the water while the hydrant is removed. This attachment is bolted to the hydrant-pot the hydrant itself being set upon this attachment.

An automatic relief-valve, operated by a balance weight, is an improved form in such valves, connected with hydrants.

The following is a list of the number of hydrants, set in Boston, up to January 1, 1878:

	Lowry.	Boston.	Post.
City proper.....	429	874	10
South Boston.....	128	348	..
East Boston.....	99	185	6
Roxbury.....	651	103	13
Dorchester.....	553	42	34
West Roxbury.....	84	19	175
Brighton.....	57	13	116
Total 3939.	2001	1584	354

The Lowry has a barrel of 9 inches in diameter. The Boston or Wilmarth a barrel of 3 inches in diameter. The Post has a barrel of 6 inches in diameter.

The Post-hydrant is of recent introduction and is used principally in the suburbs.

AIR-COCKS

require no particular mention, being but simple affairs, sometimes very similar to the ordinary service fitting, and subject to any alteration or improvement that the genius of a superintendent may suggest.

METERS.

The most popular of meters in Boston at the present time is that known as the Worthington meter, manufactured by H. R. Worthington & Co., Broadway, New York. It is giving general satisfaction. The sizes in use in this city range between $\frac{5}{8}$ in. and 4 in. and in the total number of 1,082 there are 686— $\frac{5}{8}$ in., 333—1 in., 46—2 in., 13—3 in., and 4—4 in.

A few of the description known as the Johnson meter are in use. This is a single piston meter manufactured in Boston and is comparatively new.

Concerning the correctness of meters, the Worthington has proved itself satisfactory in this regard, and is well reported upon by the Water Works officials.

SERVICES.

The services generally run now-a-days in Boston are of lead pipe. It has been tolerably well determined that Cochituate water suffers immaterially from its contact with lead; and that only for a limited time.

A cock is screwed into the charged main, without the slightest difficulty by an invention of Mr. E. R. Jones—now used in a great number of cities—by which the pipe is bored, tapped and the connection made without any inconvenience from any pressure of water whatever.

The service pipes are carried to within the exterior walls of the water taker's premises.

Besides the cock at the main, should one connection with the main serve to supply several services, at T or Y junctions cocks, are used unsparingly where required to serve the purpose of cutting off or to prevent inconvenience from becoming more than local.

The services range between $\frac{5}{8}$ in. and 2 in. in diameter. The original material used was wrought iron, uncoated, but from their filling with rust and so quickly becoming defective, as soon as unfit for service they were, and are, replaced by lead.

MYSTIC DEPARTMENT.

One of the factors in the Boston Water Works System is the Mystic supply, once operated by a distinct management, and designed originally for the supply of Charlestown and Chelsea, northeasterly suburbs of Boston proper. Early in 1874, the annexation of several of the outlying districts took place, including Charlestown, but the water works remained under its own officers until 1876.

Having been constructed to supply a certain necessity—independent in the first place of the chief title under which it now ranges—some information regarding its early history may be of interest.

Early in our perusals of the documents we have studied, we find that although in Charlestown the need of a water supply had been felt for many years, no action took definite form, until the city of Boston, in 1849, obtained an act to supply East Boston with Cochituate Water. This created some agitation, but we have to pass to April 13, 1854, to find that “sundry gentlemen, interested in the Cambridge Water Works, procured from the Legislature the right to supply Charlestown with water, under the name of the Charlestown Water Works.” No particular source was mentioned in the grant, and it was not until the following year that any important investigations were made, as it was generally supposed that either Spot or Mystic Ponds would be used. These will be found, on Plate 1, between five and six miles to the northwest of Charlestown. Mr. Henry Hubbard, C. E., made the requisite surveys of the resources and quality of Spot Pond, and showed that, while qualified as to quality, it lacked in quantity, and this, added to the value of mill privileges in its region, rendered its adoption inadvisable. The latter objection, however, principally operated in turning the attention of the authorities to Mystic Lake, the fee of which was supposed to belong to the commonwealth of Massachusetts.

Little appears to have been done until 1857, when the right was obtained from the Legislature to contract with other companies. The Company proceeded to make contracts, and selected and staked out a site for a reservoir on Bunker Hill, with a view of using the waters of Fresh Pond in Cambridge, a lake close to the latter place, to the west of it. The city of Cambridge conclusively proved that this, their source of supply, was quite inadequate

to their own requirements whenever the city should be more than half supplied, and therefore obtained a perpetual injunction to restrain any infringement on their rights.

In June, 1857, the Company's engineer was instructed to make surveys and plans for a supply from Mystic pond, and as it was then the design to furnish Chelsea and East Boston, the plan proposed was to raise the water to a reservoir on Powder Horn Hill, in Chelsea, and from this also supply Charlestown. A favorable consideration was awarded this plan, and it was submitted to the authorities of the various cities by the mayors of Charlestown and Chelsea.

The attention of the City Council was formally called to the importance of action in this matter by Mayor Dana, in September, 1858, and also in his inaugural of January, 1859.

This, the first organized plan for a water works system for Charlestown, failed, when in February, 1859, application was made to the Legislature to draw water from Mystic Pond, because the Company omitted to give proper notice to the towns interested.

The increasing requirements of the city had made it evident that more energetic action was necessary, and in August, 1859, the City Council authorized Mayor Dana to obtain a charter to supply the city with pure soft water. Messrs. George R. Baldwin and C. L. Stevenson were appointed engineers, and detailed scientific examinations were made of all the sources within 15 miles of the city. These resulted in the finding for Spot and Mystic Ponds as being only available; with regard to the former the statements before made were only corroborated in these later researches. Spot Pond, from the favorable conditions belonging to it, in its elevation, position and purity, has undergone more minute examinations than any other source in the neighborhood. The following reports concerning it will show how nearly all the investigations agree on many points: Professor Treadwell, in 1825, estimated its yield at 1,600,000 gallons per day. Loammi Baldwin, in 1835, did not quite sustain this estimate, though substantially agreeing with him. In 1836, R. H. Eddy, C. E., proposed this pond as a source of supply for Boston, the deficiency to be made up by pumping from the Mystic. In 1836 and 1838, Messrs. Treadwell and Hale, Water Commissioners, accurately measured the flow, and found it for these years to be 1,700,000 gallons per day. In 1839, Mr. James F. Baldwin, Water Commissioner and Civil Engineer, estimated its yield at 1,480,893 gallons per day. The next examination took place in 1845, and Mr. J. B. Jervis, Engineer of the Croton Water Works, and W. B. Johnson, C. E., being appointed Water Commissioners for Boston, took the matter in hand. They were the first to apply to the gauging the test of measuring the area of country draining into the pond, and the yearly rain-fall. The water the pond can furnish being a certain percentage of the amount of rain-fall on the drainage area, these deductions would seem to be conclusive. They found the yield to be 1,500,000 gallons per day, derived from a drainage area of 1,100 acres; the extreme elevation of the pond ac-

counting for the limited drainage area. In 1857, this pond was suggested as a source of supply for East Boston; but it was shown that the 16,000 inhabitants, contained in that ward, were then using more than it could supply.

In January, 1860, application was made to the Legislature for "a grant of the necessary powers" to enable the city of Charlestown, either by itself or in connection with the city of Chelsea, to obtain a supply of pure soft water. The petition was referred to the committee on "Mercantile Affairs and Insurance," and it encountered a severe opposition. Parties interested around the ponds, in the mills, the various land-owners, the city of Boston, Board of Trade, merchants and ship-owners, all opposed it, no less than six counsel appearing in the case. After thirteen protracted hearings and personal examinations, the committee, with but one dissentent, reported that:

"There was an existing necessity for pure water in Charlestown;"

"That a source of supply was at hand;

"That water could be readily obtained from Mystic Pond in an economical manner;

"That it could be done without great injury to private rights;"

"That the city of Charlestown was prepared to carry into effect the project proposed; and

"That the navigation of Mystic river and the harbor of Boston would not be injured by the plan, if carried into effect."

The bill passed both houses in the Legislature by large majorities, after severe contest, but was vetoed by Governor Banks on the ground of possible damage to Boston harbor, and it was referred to the next General Court.

The absolute necessity of a water supply being positive, Mayor Dana applied to the Legislature, at its extra session in June, for permission to obtain water from the Boston works. The act was passed June 12, 1860; but the Cochituate works being barely ample for Boston alone, (as since shown) all efforts to obtain other than a temporary supply failed.

The veto of Governor Banks being based on the probable damage to Boston harbor by the proposed dam at the outlet of Mystic Pond, investigations on this head were ordered, and Mr. Stevenson directed to test the effect of the ebb and flow of the tide, in Mystic river, on Boston harbor, and also what disarrangement would likely ensue from building the proposed dam. The U. S. Harbor Commission was ordered to make similar examination, so the city and commission acted in concert.

Mr. Stevenson's report to the city was made December 29, 1860, and his conclusions were as follows:

"*First.* That as a tidal basin, Mystic river is of the utmost importance to the preservation of the channels of Boston harbor. That its value as such at present extends only to a point between Medford and Mystic Pond; and that said pond is not a tidal reservoir of present value to the harbor.

"*Second.* That the fresh-water flow from the Mystic Pond is not appreciable on the harbor; and that a large portion of its flow is detrimental to the river.

"*Third.* That the erection of a dam at the outlet of Mystic Pond, as proposed by the city of Charlestown, will not injuriously affect Boston harbor or Mystic river, but on the contrary may be so constructed as to benefit both."

The Harbor Commission rendered its report in February, 1861, with some facts as under:

"That it is only during the dry season that Mystic Pond can be classed as a tidal reservoir; and that even then the presence of the tidal wave in the basin is scarcely appreciable.

*That the outflow from Mystic Pond does not produce a measurable effect upon the times of the currents in Boston harbor below Charlestown."

They recommended, however, that it was inexpedient to make the changes proposed by the city of Charlestown, as the lower pond *might be converted* into a tidal reservoir of value to the harbor.

In 1861, the matter was again brought before the Legislature, and the second committee reported favorably upon it. Considering, however, the stubbornness of the opposition, and the rapidly increasing wants of the city, the required removal of extensive erections on the Lower Mystic Pond, and the consequently enhanced cost of the works; to avoid risking another year's delay, the city resolved to limit its operations to the Upper Mystic Pond.

The act under which the works were constructed was passed in March, 1861. By it the city was authorized.—"To take, hold, and convey by steam, or other power, to, into, and through the said city, by suitable aqueducts or pipes, the waters of Mystic Pond, so called, in the towns of Medford, West Cambridge, and Winchester, and the waters that may flow into and from the same, and may also take and hold, by purchase or otherwise, any land, real estate or water rights necessary for erecting, laying and maintaining, and may erect, lay, and maintain such aqueducts, pipes, dams, gates, pumps, bridges, reservoirs, embankments, water-ways, drains or other structures, as may be necessary or convenient to ensure the purity of the waters of said Pond, or the ponds and streams running into it, or to convey said waters into, and for the use of the said city of Charlestown, etc.

The City was also authorized to supply Boston, Chelsea, and the towns through which the line of aqueduct may pass. It is limited to the use of the waters of the northerly division of Mystic Pond, and can raise its waters 7 feet above its original level.

The act was accepted by the citizens on September 10, 1861. On November 15, an ordinance to regulate the proceedings of the commissioners was passed. On December 10, Edward Lawrence, Matthew Rice and Geo. H. Jacobs were appointed commissioners; they were organized on January 8, 1862, and on April 5, C. L. Stevenson was appointed Chief Engineer, with George R. Baldwin as consulting Engineer.

On September 27, 1862, work was commenced, with appropriate ceremonies, on Walnut Hill Reservoir.

In February, 1863, an additional act was obtained for the temporary lowering of Mystic Pond outlet, to facilitate construction.

The line upon which the work has been built was adopted, after a careful examination of all feasible routes, on May 24, 1862, and during that season contracts were made for nearly every portion of the works.

The construction of the Engine House was commenced early in 1863, by Messrs. W. W. Bray and John B. Wilson, and was successfully completed in 1864.

On November 29, 1864, the water was formally introduced into the City with imposing ceremonies.

SOURCE OF SUPPLY.

Mystic Lake from the upper or northerly portion of which the supply is taken, is located in the towns of Medford, Arlington and Winchester, 6 3-5ths miles from Charlestown square. At the level of flowage, authorized by the Act, it has an area of about 200 acres, with a storage capacity of 380,000,000 gallons of water. Without taking into account the areas of the water surfaces of the ponds and streams lying within the drainage limits, and the brooks etc., rising in Reading, Wilmington and Woburn, all of which empty into the Lake, the area of the drainage basin of the Mystic Lake is 27.5 square miles. The numerous ponds in the basin serve to check the too rapid discharge of the rainfall into the lake and thence into the river; but nevertheless the discharge is rapid.

The geological characteristics of the basin are, that the greater part of its length and breadth is composed of a deposit of gravel and sand of a considerable depth, underlaid with primitive trap of the common greenstone variety, which crops out on the hills occasionally. It is apparent, therefore, says Mr. Stevenson, that "absorption of the rainfall must be rapid, and consequently with a minimum of loss by evaporation, while the water is gradually and equally conveyed to the water courses which feed the pond." Mr. C. L. Stevenson, the Engineer who constructed the works, remarks that: "A district of this nature is, therefore, one favorable to a high rate of drainage." It will be noticed also, by a glance at the map, Plate 1, that the lake is very favorably situated with regard to its drainage district, being situated at the extreme southerly edge of it, which fact coupled with the other conditions above mentioned, give promise of a steady and regular supply, at least until frost solidifies the surface, when in the spring freshets ensue with their consequent waste.

The fluctuations of the rainfall and other causes have to a certain extent disturbed these promises.

From the report of the Chief Engineer, published in 1865, we note his estimate of the safe daily available yield of Mystic Lake to be 30,000,000 gallons. There have been days and possibly weeks, since the works were completed, when this amount and a large quantity in addition thereto, actually ran to waste over the *overflow* at the Dam; but of late years, the consumption has so largely increased, and years of drought have supervened to upset all the theories relative to computations of supply on the average rainfall basis, that more than once, *water-famine* has been threatened, and the most stringent precautions taken to avert such a calamity.

This result is however in a large measure due to the lack of sufficient storage capacity in the present system; no such fear need ever have been entertained, were all the reservoirs of the Mystic Valley utilized in this regard.

The following table gives the rainfall and approximate quantity of water daily consumed from the Mystic Works, since 1866:

Year	Total yearly Rainfall ins.	Approximate daily quantity of water Consumed, in gallons.	REMARKS.
		Less than	
1866	40.48	1,000,000	
1867	42.10	1,300,000	Extended to Chelsea.
1868	40.12	1,000,000	Extended to Somerville.
1869	37.71	2,500,000	
1870	24.65	4 000,000	Water let on to East Boston.
1871	24.84	5,000,000	Extended to Everett.
1872	45.71	6,800,000	
1873	48.60	7,700,000	
1874	34.14	7,600,000	57,000,000 gallons supplied, in all, to Boston. East Boston shut off from April 21, to Dec. 2.
1875	48.06	7,500,000	
1876	47.00	8,825,000	
1877	41.60	8,378,000	

The rainfall was measured at Mystic Lake. It will be seen, that while the fluctuations in the rainfall have been very marked, with but trifling exception, the resources have been, and are being drawn upon in a largely increasing ratio year by year.

In the year 1874, when the necessity of increased duty was being agitated in Boston, very careful investigations were prosecuted in the Mystic region with the view of a possibility of making that district available to its fullest extent. From the reports published upon the completion of these labors, we gather more reliable information with regard to the Mystic source of supply and its capabilities. Independent of what was once Boston proper, the rapid increase in the population of Charlestown and its surroundings, and to which the Mystic furnishes with water, will soon necessitate further storage room. The population is now estimated at over 100,000 souls and the computed decennial increase, taken on the most moderate base calculated since 1800, at 40 per cent. will give, in 1886, 140,000; this number drawing a liberal supply will more than tax the capabilities of Mystic Lake in a dry season, unassisted from other sources.

The following information we take from Mr. D. W. Cunningham's Report to the City Engineer of Boston, dated August 21st, 1874; the result of the investigations before referred to:

"It will, however, be superfluous for me to demonstrate, by a list of the dry years recorded in the neighboring towns, that for a year of drought we may not count on more than 30 inches of rainfall, and that but 40 per cent. of this can be collected for use.

I shall therefore consider that this point has already been proved, and assume that 12 inches of annual rainfall is the yield of the district in a year of drought.

The drainage area of the upper Mystic, as found by accurate survey, is 27.75 square miles; to obtain the quantity of water which may be had from this area, without the lower pond, we will deduct the area of the water surfaces, or 1.58 square miles, and there remain 26.17 square miles; 12 inches of water on this area is equal to 5,457,632,400 gallons annually. This would be equal to 14,952,418 gallons per day.

The storage capacity necessary to utilize this amount must be equal to 1,690,208,272 gallons, or to a supply for 113 days."

This number of days is obtained by apportioning the amount of storage necessary to carry over the surplus collected water, when in excess of the demand, in order to furnish a supply when the rainfall falls below such demand.

Within the drainage area of the upper Mystic there are practicable storage facilities to accommodate the total yield of the district.

Returning to what Mystic Lake is actually at present capable of supplying from its reservoir of 380,000,000 gallons, in the severest known seasons, we gather from Mr. Davis' report for 1874 on additional supply, that, from the experience gained on the Cochituate drainage area for three months in a very dry season, it was found that the natural daily flow of the streams may be reduced to an average of 130,000 gallons per square mile of water shed.

"During such a period there would be a daily flow into Mystic Lake of 3,575,000 gallons, from its drainage area of, say, $27\frac{1}{2}$ miles. Of course the Lake will yield in addition to what it receives the quantity it holds in store. If the lake be full, it will supply 4,220,000 gallons per day for three months, from its storage above; therefore its average total daily yield for that period will be 7,795,000 gallons."

Mr. Fteley, Resident Engineer, on the works for the New Supply to Boston, was also instructed, in 1874, to make careful experiments upon the waste of water flowing over the *overflow* dam at Mystic lake. These experiments were made with accurate instruments, and so arranged that calculations could readily be made therefrom, with the aid of the records kept at the works relative to the amount of rain actually collected during any year.

The test was applied to the year 1871, and it was found, that the amount of rain collected was equivalent to 12.92 inches in depth upon the whole water-shed, which is 43.2 per cent. of the rainfall as measured by the gauge of the Mystic works. There can be no doubt, says Mr. Davis, after an examination of the records kept at various places, that the results obtained from the Mystic gauge in that year are not applicable to the entire valley.

From the above it will be seen, that the yield of the Mystic valley for 1871, amounting according to Mr. Fteley to an average daily supply, of 17,249,000 gallons, exceeds Mr. Cunningham's estimated yield by nearly 3,000,000 gallons per day; but as Mr. Davis further remarks, "that it is not probable that the rainfall, as an average for the whole valley, was less than 40 inches, (the Mystic gauge recorded 29.9). The assumption, therefore, that from a rainfall of only 30 inches not more than 12 inches would be collected, seems reasonable and proper.

We now come to the purity of the Mystic supply. In consequence of the numerous complaints, founded, doubtless, in part from a knowledge of the local conditions about the source, as well as on more than one occasion from actual defect in the quality of the water consumed in Charlestown or elsewhere, many tests have been made throughout the Mystic valley by the most eminent chemists on this subject. The results of these experiments and tests have generally coincided.

The Mystic valley, besides containing a large population within its limits, in the form of small towns or otherwise, whose sewage up to the present must in large part have naturally found its way to the lower levels, is the site of some 82 factories—more than a third of which are tanneries—employing some 3,500 hands. The refuse from this large manufacturing interest, situated as the tanneries must be, on the banks of the streams, also finds its way into the lake.

Prof. E. N. Horsford of Cambridge, in his report on the analysis of the Mystic water in 1873 in conclusion says: "Of its salubrity as a drinking water, it will compare well with the best waters in use for city supply. It has experienced no appreciable deterioration since its introduction.

If the contributions from factories and domestic sewage continue to be no greater than they are now and have been hitherto, and the volume of water remains the same, the self purifying power of the water will be adequate to maintain its salubrity.

In case the factory drainage and domestic sewage discharging into the tributaries are steadily increased, and especially if the supply of water be from any cause diverted or diminished, a time will come when the self purifying power of the water will be overborne. When such time comes independent drainage for the factories and domestic sewage to a point below the entrance to the aqueduct will restore the balance."

In 1874, a Medical Commission was appointed to examine and report upon the various sources of supply available for Boston: in it they gave it as their decision that the Mystic was decidedly inferior compared with either the Charles, Sudbury or Shawshine rivers.

The necessity of a system of sewerage to remove the objectionable causes of impurity in the upper Mystic,—for some years adjudged necessary looking towards future requirements—assumed definite and practicable shape in 1877. On August 6th Mr. F. H. Tarbox was appointed Superintendent of Construction, with Mr. W. F. Learned, Assistant Engineer in Charge.

The sewer is located in the towns of Medford, Winchester and Woburn. Commencing at the outlet in Lower Mystic Lake just below the Dam, it pursues a northerly and north-easterly direction for some five miles in all.

The main sewer is built of brick, and is 28 inches by 26 inches wide. It is 11,857 feet in length, 11,228 lineal feet is in "single course work." The remainder is in double courses, under railroad tracks and in exposed positions. At its outlet and for a length along the railroad embankment, cast iron pipes 24 inches in diameter are used.

The crossing of the Abbajona River is effected by means of two wrought iron pipes, one within the other, to avoid risk of freezing. The full capacity of the sewer is allowed for by enlargements etc. when necessary.

37 manholes and 10 flushing tanks have been built in the main sewer line; the manholes are located 250 feet apart, and the flushing tanks 1,000 feet one from the other.

The bricks were furnished by the Bay State Brick Company at a contract price of \$7.50 per thousand. The cement was furnished by D. Roby & Co., of Boston. The wrought iron pipes were made by Messrs. Lally & Russel of South Boston, and the cast iron ditto, by Jesse W. Starr & Sons of Camden, N. J.

The pipe sewer including all its branches, and which extends beyond the brickwork, has a total length of 11,644 lineal feet. About 8,200 lineal feet of this will be Akron-sewer pipe 15 inches in diameter and 1000 feet 10 inches in diameter. All branches are of 6 inches in diameter. 35 manholes and 10 flushing tanks are located on this line, in like proportion as the main sewer.

Messrs. Lewis & Willett supply the Akron Sewer, pipe delivered at Winchester.

The main sewer is completed and it is fully expected that the entire length will be in working order by July 1st, 1878. Up to January 1st, 1878, \$73,000 had been expended on this work, including labor and materials.

This sewer is expected to entirely remove all possible cause for complaint against Mystic water. It will necessarily reduce the supply to the extent to which the sewer is used, but the advantages accruing from its adoption will make themselves felt in many ways.

THE WORKS.

The Mystic system comprises:

Dam and Overfall.

Conduit, Gate-houses, Waste-weir, etc.

Cast-Iron Mains under Mystic River, Bridge, etc.

Engine House and Pump Well;

Pumping Engines;

Force Main;

Reservoir and Appurtenances;

Supply Main and City distribution.

Dam and Overfall. The Legislature having restricted the City to the use of the upper portion of Mystic Lake, necessitated that the Dam should be constructed at the narrows, or at that point where projections of land on either side gave the form of a figure 8 to the plan of the lake.

Across this strait, and along the low shores, until the proper elevation is reached, a dam, 1560 feet long is formed. It is composed of earthwork, puddle and concrete, and although some difficulties were experienced from

quicksand and poor foundation, it was successfully carried to completion. The height of the Dam is 11 feet above high water mark of Boston harbor, on the original level of the lake, and 4 feet above the authorized flowage level. Two rows of 6 inch sheet piling, 15 ft. long, were drawn to an average depth of 11 feet below the water line, and extending along the main portion of the Dam some 550 feet. Between these rows, 5 feet apart, a puddle wall 11 feet high, of carefully prepared materials from the banks of the old Middlesex canal is built, and against the interior of the lower side, as an additional precaution against infiltration or percolation, a wall of concrete masonry of an average thickness of 18 inches is laid. (See Plate 3.) A single row of 6 inch sheet piles extends a further distance of 330 feet, protected on the upper side with concrete and puddle walls. Earthwork forms the bulk of the Dam, having a surface width of 15 feet sloping therefrom, on each side, at an angle of 2 to 1. From a little above water line on each slope and extending to the bottom, a layer of puddle 2 feet thick, with 1 foot of rip-rap on its surface, serves to prevent both leakage and damage from the wash of the water.

The overfall of the dam is constructed of cut granite, rock face, masonry and consists of five piers and two abutments, with six waste pumps of six feet each. The distance between abutments is 80 feet, the piers being 5 feet wide at the base and 11 feet long in the direction of the stream. The whole structure rests on piles driven into the quicksand 18 feet, with a covering of 18 inches of concrete, and an apron or base course of cut granite. The lines of 6 inch sheet piling extend on both sides of the base of the overfall, and the concrete masonry covering the piling extends out thereto. An isometrical view of a portion of this overfall, given on Plate 3, will explain more fully, than words, the general details. Two grooves will be observed on the faces of the piers and abutments into which stop logs, 6 inches thick drop to regulate the height of the water in the lake. Up to a certain height the space between the planks is filled with puddle to prevent leakage. A wooden bridge now spans the overfall, in which trap doors are arranged over each bay, to facilitate the regulation of the stop-planks. According to the laws of the State, a fish-way has to be provided at all dams to allow of the fish ascending the lakes and streams. There was an endeavor made to accomplish this by a series of steps about 6 inches in depth. This was found to be a failure, the apparent force of the series of diminutive water falls opposing a decided obstruction to the efforts of the fish. The form at present in use known as the "Foster fish-way," appears a decided success. It is constructed of heavy planking, forming a deep trough, inclined from the top of the top plank to nearly the surface of the lower water, where it turns with an abrupt right angle and discharges in that angle into the water below. It increases in width as it descends. In the interior of this trough from each side, alternate transverse partitions extend some two-thirds of the width, terminated at each end with right angled projections up stream. This arrangement breaks the force of the water fall, forming in each division of the

trough eddies and back water, enabling the fish to rest on their upward journey as often as they choose. Notwithstanding the force of the stream, a considerable time is occupied by a piece of wood thrown into the upper end, before it reaches the lower level. A marked success has attended this experiment, the fish in certain seasons becoming almost jammed in the chambers of the fish-way.

GATE HOUSE.

At the easterly end of the Dam, and at a short distance from shore,—for the sake of pure water and depth—stands the Gate House, the northern extremity of the Conduit, and in which are placed the gates and screens to regulate the supply from the lake. It is constructed of granite masonry externally, and lined with brick-work; the whole executed in hydraulic cement. A quicksand foundation and the great depth of water necessitated the construction of a coffer dam, of which when the building was completed, only the side facing the leak was removed; the other three sides being left to add to the stability of the work. The structure is supported upon oak piles driven into the quicksand, upon which lies a bed of concrete, surmounted by a flooring of cut granite masonry, 1 ft. 6 in. thick. The lower story or gate chamber is externally, 22 ft. .0 in. x 18 ft. .0 in. divided into two gate or receiving chambers and two screen chambers, the latter uniting at the conduit entrance by an opening in the partition walls. The water from the lake passes into the gate chambers through two openings 4 ft. .0 in. x 4 ft. .0 in., protected by vertical cast iron gratings. There is provision just within the external walls of the gate chambers, by means of grooves in the masonry into which stop planks may be fitted, that the gates may be repaired or water shut off when necessary.

The passage of the water from the receiving to the screen chamber and conduit is regulated by two draw gates, three feet by four. These gates are raised and lowered by hand wheels and screws worked from the flooring in the upper story or superstructure. Copper mesh screws, inclined at an angle, are fitted in the screen chambers easily removable for repairs. A neat face-brick gate-house is erected over the chambers.

WASTE WEIR.

Before proceeding with a description of the conduit, some remarks upon the waste weir, situated very near to the gate-house above noted, and the ventilator, will save recurrence to these points again. The waste weir is designed to carry off the surplus water into the lower lake, and to regulate the head in the conduit beyond it. Owing to the very low level and the little difference between the water within and without the conduit, it was constructed of very ample dimensions. Practically, it consists of a chamber parallel to the conduit, 39 feet long by 15 feet over all, whose invert is quite similar to that of the conduit.

For the above distance the exterior side walls of both conduit and chamber are carried up vertical in brick work, in all about 11 feet above the

bottom of the concrete foundation. The inverts are semi-circular, and at the springing line the partition wall terminates with a grooved course of granite; above this, the chamber is divided into 5 openings of 6 feet each, the arches of which, supported on grooved granite upright columns, sustain a share of the arched covering to the whole structure. Into the grooves in the partition walls and running parallel with the length, of the chamber, stop-planks are fitted and the height of water regulated thereby. Access is gained from the surface of the ground by trap doors seated in a granite curb supported by brickwork extended from the top of the chamber; these doors are situated immediately above the stop planks. The waste discharges into the lower lake through a brick conduit at right angles to the chamber, at its southerly extremity, the lake end being constructed of granite masonry, to preserve it against ice, in which stop planks are also used to facilitate measurements of discharge or waste.

VENTILATOR.

Only one ventilator was built; it is situated near the south end of lower Mystic Lake. It is of brick masonry, in plan a six pointed star, with an equivalent diameter of 6 ft. 0 in., and is ten feet high, the roof being arranged to overhang, to protect the opening to the conduit.

CONDUIT.

The conduit extends from the lake to the pipe-chamber on the north bank of Mystic River, conveying the water to the iron pipes passing under the bed of the same, a total distance of 7,453 feet. It is constructed of hydraulic brick masonry, generally 8 inches thick,—this dimension is increased to 12 in. on the length between the Waste-Weir and Gate House. (See Plate 3). In shape it is oviform, 5 ft. 8 in. in length, and 5 feet wide, interior dimensions; the base being semi-circular 5 feet diameter, the upper segment having a rise of 3 ft. 2 in.

The whole exterior of the brick-work is coated with hydraulic cement mortar. The level of the inside of the invert at the lake is 4 ft. 2 in. below tide water and 11 ft. 2 in. below the line of authorized flowage. The total fall to the pipe chamber is nine (9) inches, being a grade of .01 per 100, equal to about 6 inches to the mile. The first 3,000 feet of the conduit known as the Pond Section, was necessitated by the legislature compelling the city to confine their works to the upper Mystic Lake, and was attended, in its construction, with marked and continued difficulties. It passes along and around the easterly side of the lower Mystic, a shore line of steep side hills, with abrupt and sudden bends and changes in direction. To procure an admissible alignment, the work had to be carried through heavy cuttings, and across deep bays; some idea of the obstacles to be overcome may be deduced from the fact that the excavation for foundations extended 5 or 6 feet below the water line of the pond, and that costly and constant pumping had to be resorted to. The soil generally was extremely porous, consisting of coarse loose gravel, while in some places mud and quicksand were encountered

upon which a man could not stand. The pumping capacity required in some places equalled a million gallons in three hours. The difficulties from water was in a small degree modified by anticipation, and an act obtained to construct a system of tide gates at the outlet of the lower Mystic, by which the water was lowered some two feet.

Reference to Plate 3 will show the average method of forming foundations; in all cases the conduit is bedded in concrete, 3 or 4 inches beneath it, and extends up its sides at least 2 ft. 0 in. But modifications were constantly necessary; in some places sheet iron was used on plank, while the planking and stringers were altered in scantling and arrangement at every change of soil.

Upon the lower section, near Mystic river, a locality was reached abounding in land springs, which caused leaks in the conduit, and upon examination it was found preferable in three cases to give the springs free access to the conduit, from which no evil of importance has resulted.

The earthwork of the conduit was commenced in 1862 and the whole finished in 1864. The greater part was performed under a contract with Mr. McDonald, of Albany N. Y., under the immediate inspection of Mr. Albert Whiting.

Manholes giving entrance to the conduit, are situated along its length at intervals of about 1500 feet. They are covered by iron traps seated in granite curbs, with 2 ft. 6 in. of earth over the whole to prevent disturbance by unauthorized individuals. Plate 3 gives an elevation of a man hole.

THE PIPE CHAMBER.

The conduit terminates at the pipe chamber, into which it discharges, which is situated on the north bank of Mystic River. It is a structure whose basement is 18 feet x 15 feet, supported on concrete on a plank foundation, resting on marshy soil, full of quicksand, upon which some difficulty was experienced in putting in the concrete. To ensure stability, inverts are turned in brick, as a flooring to the delivery and pipe wells. The level of the soffit of the conduit arch is 9 in. above mean high water, and the floor level of the wells about 12 feet below that of the conduit soffit. It is constructed chiefly of hydraulic brick masonry, and is interiorly divided into three portions, a receiving well 11 feet x 7 feet, into which the conduit empties, which opens into two delivery wells, about 5 feet x 4 feet through openings 3 feet x 3 feet . 6 inches. From the receiving well a waste pipe, 30 in. in diameter, is carried to the Mystic river to admit of emptying the conduit if necessary, and grooves and stop planks are also provided immediately facing the conduit opening to allow of repairs in the chamber. The level of the bottom of the waste pipe is that of the underside of the brickwork of the conduit invert; it is fitted with double gates 3 ft. 0 in. square, facing in opposite directions, the outer being intended to prevent any inflow of salt water during high tides; the inner to prevent waste from the receiving chamber. The gates into the delivery chambers

are similar in size and construction to those used at the Gate House, Mystic Lake and are to regulate the flow into the iron pipes passing under Mystic river. Double sets of copper screens are placed in the delivery, or pipe-chambers to prevent eels or fish from entering the pipes. The partitions in the sub-structure of this building pass upwards to the floor of the super-structure above, from which the gates are regulated by hand wheels etc., and the floor so constructed that easy access can be obtained to the regions below. A brick, cottage like edifice rests upon the heavier building below. The total depth of the sub-structure, to the bottom of the brickwork is 17 ft. 9 in.

CAST IRON MAINS UNDER MYSTIC RIVER.

From the pipe-chamber the water is conveyed to the pump well of the Engine House by two cast iron mains passing under the Mystic river. This was obligatory by the terms of the Act. The pipes are 36 in. internal diameter, 1 inch thick, and lay in 12 feet lengths. Special castings with conical mouths, are built in to the wall of the pipe chamber, 5 ft. . 0 in. from centre to centre of each, which dimension continues throughout the distance of $485\frac{1}{2}$ feet from pipe-chamber to pump-well. The level of the bottom of the inside of the pipes is about 5 ft. . 7 in. below the level of the surface of the invert of the conduit, or about 11 ft. . 0 in. below mean high tide, and this level is maintained throughout the whole length. At the river crossing, it was necessary to construct a coffer dam; two rows of sheet piling were driven, the inner rows of guide piles being 13 ft. . 0 in. centre to centre; when the pipes were laid, the coffer dam was removed with the exceptions of the inner rows of piles which were used in constructing a bridge to connect the works. This is a wooden bridge, and serves also to protect the line of pipes, but does not need particular description. Half the width of the river was completed before the other was commenced. For the 150 feet under the river, the pipes were bedded in cement concrete, 6 in. thick under the centre, which thickness also surrounded them; but for the other remaining distances, they were bedded on 6 in. of concrete, and the two pipes surrounded with puddle. Either of these pipes with the extra head imposed upon it by its extra depth, is capable of delivering all the conduit can supply; but the two were laid to guard against accident. The joints are made in the ordinary way by lead and gasket, and the pipes coated with coal-tar at 300 deg. Fah. of heat.

ENGINE HOUSE AND PUMPING-WELL.

The engine house is situated on the southerly bank of the Mystic River at about 200 feet from the water's edge. It embraces under one roof, the pump-well, boiler and engine rooms, and repair shop, and is 120 feet long by 58 feet wide. It is constructed of red face brick, with freestone trimmings resting on a granite underpinning. In its present form it is considerably enlarged from its original dimensions. Its length is nearly at right angles to the supply main above described.

The boiler room floor is 16 ft. 6 in. above the level of the bottom of the pipes before mentioned, and the engine room 20 ft. 6 in. above the same point. The boiler room, the easterly portion of the building, is about 72 ft. .0 in. x 53 ft. .0 in. and has two stories; the lower one contains 8 boilers each 16 ft. .0 in. x 5 ft. 3 in. diameter, with the necessary appurtenances, and a Fairbanks scale for weighing coal and ashes, both of which are handled on a small car running on a track leading from the coal stores facing the southerly side of the brick room, and traversing the room immediately in front of the furnaces. A portion of the second story is used as a hall and the remainder for tools and stores.

The engine room is 83 ft. .0 in. x 53 ft. .0 in. with a headway of 23 ft. .0 in. in the clear. It contains 2 Worthington Pumps of a capacity of 5,000,000 gallons per 24 hours, and 1 equal to 8,000,000 in the same time.

The coal shed was constructed by excavating into the embankment so that the floor on the lower end is on a level with the boiler room floor, with which it communicates by a tunnel running beneath the passage way between the coal shed and smoke stack and the boiler room. The roof is on a level with the roadway, so that teams drive directly on and dump the coal through scuttles into the shed, from which it is carried to the boilers by the car spoken of before. It is calculated to contain 1,000 tons of coal. The chimney, an ornamental buttressed stack is located near the coal shed, about the middle of the block, on the opposite side of the passage way referred to, which is 16 ft. .0 in. wide. The flue is carried from the top of the boilers, across the passage way by protected cast iron pipes 30 in. diameter and into the chimney by way of the coal shed. The chimney is of brick masonry 105 feet high starting from a granite base 15 ft. .0 in. square.

The pump-well is located on the southerly side and under the engine room floor. It is 30 ft. .0 in. long, 11 ft. .0 in. wide and 14 ft. .0 in. deep with a capacity of 26,000 gallons at the usual pumping level. It is sunk down to and into the rock ledge, which is covered with concrete to prevent leakage from fissures etc., and upon this is laid a floor of hard-burned paving bricks upon edge. A small sub-well is sunk to a still greater depth to admit of completely drying the well, for which purpose extra suction, strainers, etc., have been furnished. The side wells are of rubble masonry lined with hydraulic brick masonry 3 ft. .0 in. thick at bottom, and 2 ft. .0 in. at top.

The supply pipes carried under Mystic River are continued through the Engine House wall and into the pump well, and wherever they pass through such walls, arches are turned over them to carry the weight, that they may be relieved of all strain but what they were intended to bear. They are bedded in the wall of the pump-well, terminating on its inner face, and the level of the bottom of pipes and the wells are the same.

The engines are worked alternately, or as required, the two smaller ones being in use together, while the larger one is stopped for repairs.

FORCE MAIN.

From the air chambers of each of the pumps, 30 inch mains are carried through the walls of the building, and in convenient localities outside unite and continue in one pipe of 30 in. diameter to the Reservoir. Check valves are placed on each of the above branches, and one on the main in advance of the functions. Waste pipes are led from the check valves, upon which gates and hydrants are fixed for local use. The force main is 3,277 feet in length, 2,100 feet of which are laid with solid lead joints. The level of this main at the Engine House is 16 ft. 6 in. above tide water, and it rises gradually to the reservoir, in which the level of high water is 147 feet above tide level. Near the Engine House, the pipes have flange joints and are bedded on masonry.

RESERVOIR.

The Reservoir is situated on Walnut Hill, in Medford, near Tuft's College. It serves both for receiving and distributing, its location and height rendering it peculiarly favorable for both purposes, and it is capable of supplying any of the towns, lying between the Charles and the northern slope of Mystic River. Its water surface covers an area of $4\frac{1}{2}$ acres, being nearly of the shape of a parallelogram, with a length of about 560 feet and a width of 350 feet. It is divided into two portions, nearly equal in extent, by a partition embankment, the top of which is 5 ft. . 0 in. below high water line. At high water it has the appearance of one basin. It is 26 feet in depth, the top of bank being 3 ft. . 0 in. above high-water mark. At high water level the capacity is 26,244,415 U. S. gallons.

The natural soil, clay, was mixed with a proper proportion of sand, and deposited in layers 6 inches thick, wetted and rolled with grooved rollers, and compressed with teams to form the embankment. The footings, where the old and new soil met, were stepped to avoid a continuous surface. Plate 3 will give the dimensions and construction of the banks. The inside slopes $1\frac{1}{2}$ to 1, are lined with puddle 2 ft. . 0 in. thick, which is covered with brickwork 8 in. thick up to a line $4\frac{1}{2}$ feet from the top, where the lining is faced and coped with cut granite masonry. This latter is composed of 3 courses of 18 in. each, with projecting coping 2 feet wide. The granite masonry has a batter of 3 in. to a foot. The exterior slopes are $1\frac{1}{2}$ to 1 and are soiled and sodded. A gravel path 8 ft. . 0 in. wide extends around the reservoir upon the embankment, which is 19 ft. 5 in. wide.

The partition has slopes of one to one, faced and covered with brickwork, and backed with puddle walls 2 ft. thick. The division of the reservoir into two parts was designed to promote subsidence, and facilitate repairs and cleansing.

The top water line is 147 feet, and the bottom 124 feet above high water level of the harbor. The bottom of the reservoir is puddled and covered with concrete 3 in. thick, and the base of the brickwork has also a founda-

*2-30" main
3,277' long
(@ 10 ft. grade 1885)*

tion and backing of concrete. A roadway 40 feet wide passes around three sides of the reservoir at the foot of the embankment.

INFLUENT CHAMBER.

The Influent chamber, which receives the water from the force-main, is situated within the easterly embankment of the reservoir, at a point opposite the centre of the partition bank. It is constructed of hydraulic brick masonry, with cut granite coping, sills and covering. The water is first received from the force-main in a square well, outside dimensions 8 ft. 0 in. x 14 ft. 0 in. and about 22 ft. 0 in. deep from the top of the embankment; the water rises in this well to about 2 ft. 9 in. from the level of the embankment, when it falls over a granite curb into two receiving chambers, each separately communicating with a division of the reservoir by means of circular brick culverts, $2\frac{1}{2}$ feet in diameter. These two chambers, 3 ft. 0 in. x 2 ft. 6 in. internal dimensions form part of the receiving well, and the partition between them ascends to the surface and extending over the granite curb forms two entrances in which by means of grooves and stop planks, water can be admitted to either division of the reservoir when required. These chambers are about 5 ft. 9 in. deep at a little above which depth the culvert leads out. On a level with the granite curb, above mentioned, a 30 in. pipe from the receiving well, passing along within the embankment, connects directly with the Effluent Gate House at the end of the reservoir; this is also closed by stop planks in grooves. Provision is made in the well for an additional force main when needed. The culverts discharge into the corners made by the partition embankment with the outer one, at which water ways are constructed, to prevent wash of flagging stone.

The 30 in. delivery pipes or wrought iron and cement, are laid upon the bottom of the reservoir, and covered with hydraulic cement mortar. They are so arranged that the water can be drawn to the effluent chamber from either or both divisions of the reservoir, or cut off from both.

12 in. wrought-iron and cement drain pipes are similarly arranged, but lead out on the northerly side. They are regulated by stop-gates enclosed in a chamber of brick and stone masonry. The drain pipes are laid under the bottom, which in each division has a fall of 6 in. to the drain inlets. The drain inlet is situated on the inside corner of the reservoir and the valve, or gate chamber, at the outside of the embankment.

EFFLUENT CHAMBER.

The Effluent chamber, or Gate House, is situated on the exterior slope of the southerly embankment of the reservoir, and is constructed of hydraulic brick and granite masonry, the top of the foundations of which are on the level of the bottom of the reservoir. The building, 28 ft. 0 in. x 23 ft. 4 in. outside dimensions, is divided into three divisions, the receiving gate, the screen, and the delivery gate, chambers. The receiving and delivery gate chambers are dry; the screen chamber, between the two, is a well 17 ft. 4 in.

x 6 ft. . 0 in. extreme width, in which the water rises to the level of the reservoir. This wet well is again divided into three portions by cast-iron partitions, with gates in connection therewith, to give complete control over the three supply mains issuing from the delivery gate chamber; the entrances to the supply mains can be closed in the wet wells by stop planks, and the gates in the delivery gate chambers repaired or removed individually, as occasion requires.

It was observed that a pipe passed within the easterly embankment of the reservoir from the Influent Chamber enabling a supply to be delivered directly to the Gate House without entering the reservoir. This pipe discharges into a well, occupying a portion of the receiving gate chamber, which is so arranged by an overflow curb and exterior receiving basin, that by means of a pipe from the latter the overflow can be carried back into the reservoir.

Two thirty-inch stop gates regulate the supply from the two mains leading from the reservoir; the delivery mains in the delivery chamber, one 24 in. and two 30 in. are governed by gates of corresponding size. Copper screens are used in the wet well, of the old fashioned type, which require frequent cleansing; the size of the building is scarcely adequate to the introduction of revolving screens in use on the Cochituate supply.

The gates and appurtenances are worked from the upper floor on a level with the top of the embankment. A handsome Gate House surmounts the well chambers, built of face-brick with sand-stone trimmings.

SUPPLY AND DISTRIBUTION.

Charlestown was supplied until the year 1870 by one 24 in. cast-iron main, leading from the reservoir to Charlestown Neck, a distance of 16,250 feet. This main had branches to Medford on the east and Somerville on the west, before it connected with the distribution system, commencing at the Neck. It had also a "blow-off" in Medford and one in Somerville, for which localities offered eminently suitable. Passing through the streets of Medford and Somerville, the "Acts" required that hydrants should be placed upon it at intervals of 500 ft.

In 1867 arrangements were made for the supply of Chelsea. A cast-iron pipe of 16 in. diameter enclosed in a wooden casing, was carried across the Mystic river by way of Chelsea bridge where the two draws in the bridge occurred, inverted siphons of 24 in. pipe were laid, boxed and bolted, and the spaces filled with concrete. The total length of this crossing amounted to 3,299 feet.

In 1868, a contract was made to supply the town of Somerville, and in the same year an 8 in. main was carried across the Mystic River to serve the almshouse and chemical works of Malden. The crossing was made by using flexible jointed pipe of the patent known as John F. Ward's, the joint of which is made with lead in conjunction with a turned socket and spigot. The length of pipe thus jointed, and resting on the bed of the river is 805

feet. In 1876, a 16 in. pipe was carried across Malden bridge, to increase the supply, and at the draw of the bridge an inverted siphon of 20 in. pipe was constructed.

In the year 1870, a new 30 in. wrought-iron and cement supply main was laid by Mr. Geo. H. Norman, of Newport, R. I., 15,205 feet long, and connecting with heavier distribution pipes in Charlestown. This addition to the supply, so long required, proved a valuable auxiliary. Since the above, a 12 in. supply pipe, for a certain portion of Somerville, was connected with the short length of 30 in., ready for a third supply, at the gate house.

According to the original plan, when the supply of Charlestown was alone, contemplated, the dimensions of the proposed pipes ranged between 16 in. and 4 in. in diameter. In rare instances, where blind alleys or such like services were required, 2 in. pipe was occasionally resorted to.

When Chelsea and Everett were added to the distribution, 20 in. pipes were laid in Charlestown to supply the increased requirements.

The description of pipe was a matter of long and earnest consideration and on account of cheapness and an already good reputation, together with satisfactory offers on the part of the Jersey City Water and Gas Pipe Company manufacturers of the wrought-iron and cement pipe, this kind of pipe was generally adopted. For the first two or three years it sustained the reputation accorded it very well, but in Charlestown it has proved comparatively of short life; and whether from the fault of the quality of cement used in its construction or what, the iron has been found to oxidize badly, and unless a faultless foundation can be assured, and perfection in laying and jointing guaranteed, it is an expensive substitute for cast-iron in the long run. It still has many advocates among experienced men, but all agree upon the necessity of thorough workmanship in the laying and making, and a good firm foundation upon which to rest. As an example of the manner in which the above pipe fails from some cause or the other, it may be stated that for the year ending May 1, 1877, 12,254 feet were taken up, only 500 feet of which was fit for further use.

In illustration of the increase in the amount of pipe and appurtenances used in connection with the Mystic Water Works system, the following table (page 44) is presented.

PIPE.

In Charlestown, the pipe used at the present time, on account of the Mystic Department having been incorporated with the Boston Water Works, is of the same specification as that for Boston, so that the remarks made heretofore upon the subject will suffice for this.

Chelsea, Everett and Somerville, according to their contracts, agree to lay and superintend their own pipe distribution, and in these districts the wrought-iron and cement pipe is still to a great extent retained, and according to report answers well.

Wrought-iron and cement pipe consists of sheet-iron rivetted into the form

TOTAL AMOUNTS OF PIPES, VALVES, HYDRANTS, METERS AND SERVICES CONNECTED WITH THE MYSTIC DEPARTMENT BOSTON WATER WORKS, 1865, 1871, 1876.

DECEMBER 31 ST, 1865.

	PIPE.												SERVICES.						
	36 in. lin. ft.	30 in. lin. ft.	24 in. lin. ft.	20 in. lin. ft.	16 in. lin. ft.	12 in. lin. ft.	10 in. lin. ft.	8 in. lin. ft.	6 in. lin. ft.	4 in. lin. ft.	3 in. lin. ft.	2 in. lin. ft.	1½ in. lin. ft.	1 in. lin. ft.	¾ in. lin. ft.	¼ in. lin. ft.	Hy- drants.		
W. I. and Cement, Cast Iron.....	974	405 3581	16557		5206	472 80	3182	22234 62	37533 505	40755 266	1544	6682				29256	135		
Total	974	3986	16557		5206	552	3182	22296	38038	41021	1544	6682	Total	97	833	6058	18666	135	
Valves.....		2	2		3	2	5	30	117	148	2	69	Total ft. Distribution Pipe 140938=about 26 miles.						
													" Service Pipe,					5483	
													" number of Gates,					380	
													" Hydrants					135	

DECEMBER 31ST, 1871.

W. I. & Cement.	17515	5980	6156	9446	11250	53497	117502	150586	26643	9856	631		
Cast Iron	974	3988	16867	200	7928	383	1615	3916	1020	11838	1274	47	1752 688 4460 5776 38555 144109 407
Total	974	21503	16867	6180	14084	9829	12865	57413	118522	168424	27917	47	1752 688 4460 5776 38555 144109 407
Valves.....		8	6	4	11	17	17	59	199	329	54		Total lin. ft. Distribution Pipe, 465065 = 88 miles. " " Service Pipe, 195387 " " number of Gates 704 " " Hydrants 407

MAY 1ST, 1876.

W. I. & Cement.		17515	3980	6950	12032	24599	62645	186,407	293007	319601	10349	
Cast Iron	974	3988	16867	200	1478	658	3533	9908	9666	15537	21018	294
Total	974	21503	16867	4180	21428	12690	28132	72543	196073	313544	52978	10643
Valves.....		8	6	4	19	21	29	89	300	468	63	

Of the above estimate of Distribution Pipe for 1896, somewhere about 30 miles must be deducted for pipe laid

Total ft. Distribution Pipe = 751555	about 142 miles.
" Service Pipe, 436087	
" " number Gates, 1007	
" " Hydrants, 650	

Of the above estimate of Distribution Pipe for 1876, somewhere about 30 miles must be deducted for pipe laid in East Boston, which is included in Cochrane quantities.

of pipe, the inside of which is lined with hydraulic cement; it is then bedded in cement and enveloped in the same. The thickness of cement in the interior of a pipe, made to equal 6 in. internal diameter, is about $\frac{1}{2}$ inch; this increases somewhat as the diameter becomes greater. The joints are made with wrought-iron sleeves, constructed like the pipe and bedded and jointed in cement.

At the foot of the above table the total length of pipe is given for the Mystic Water Works as about 142 miles. Apportioning this to the several districts we have, approximately, 28 miles for Chelsea, 44 miles for Somerville, and 14 miles for Everett. Some 30 miles included in the amount should properly belong to East Boston, and is included in the Boston distribution, while the balance belongs to Charlestown proper.

From the tables some idea may be gained of the increase of the distribution, since the completion of the works in 1865.

GATES.

The number of gates or valves distributed throughout the system is 1,007. Only two kinds need be mentioned, those of the Boston Machine Co. and the Chapman Valve Mfg. Co.; there are, however, only a few of the latter. They are of the double-disc pattern, closing down on to brass facings.

The number, included in the above gross amount, belonging to Somerville is 340, and to Chelsea 226; the larger number of the remainder are located in Charlestown, the balance in Everett.

HYDRANTS.

In the districts supplied with water from Mystic lake, viz.: Chelsea, Everett, Somerville and Charlestown, from the fact that Chelsea, Everett and Somerville lay their own mains and appurtenances, a variety in the pattern of hydrants in use might be expected. Upon looking into the matter we find such to be the case, and that the following kinds represent nearly all the hydrants doing duty: the "Lowry," Lowell, Newport, New York, Perkins, and Boston Machine Co.'s pattern. The Lowry hydrant is used for the most part in Charlestown, for out of a total of 189, 152 are of the Lowry pattern, 31 are flush hydrants and 6 post, the two latter of the Boston and Holyoke type. In Chelsea, 136 are set in all, of which 5 are flush and 131 post, principally of the Boston and Bigelow pattern. In Somerville, there are 244 hydrants, 217 of them chiefly of the Boston Machine Co.'s post design, 3 Lowry and 24 flush.

There are 67 hydrants in Everett, all post-hydrants, and 10 in Medford. In the near future, we may give a full description of the various kinds of appurtenances used in the distribution requirements of a water works system.

METERS.

There are 180 meters in use in the Mystic Department: 71 in Charlestown, 52 in East Boston, 31 in Chelsea, 21 in Somerville, and 5 in Everett.

They range in size between 4 inches and $\frac{5}{8}$ of an inch. The Worcester and Worthington seem the only types represented in this Department.

SERVICES.

The remarks pertaining to services in Boston will now serve for those of Charlestown and vicinity.

COST OF CONSTRUCTION.

In the report for the year ending December 31, 1871, we quote the following concerning the cost of construction to that date:

Salaries.....	\$ 17,644.61
Engineering, including salaries of Chief and Consulting Engineers.....	33,746.87
Land Damages.....	89,855.38
Reservoir	141,856.26
Dam.....	17,167.26
Conduit.....	129,714.30
Engine, Boiler House and Chimney.....	36,112.99
Engines	86,638.04
Grubbing Pond.....	9,393.26
Iron Pipes for Supply and Force Mains.....	108,437.10
Laying do.....	61,029.59
Pipes for City distribution.....	145,237.12
Hydrants	19,926.21
Stop-cocks.....	19,262.52
Contingencies.....	14,012.51
Roadway and Bridges.....	3,529.22
Lowering Mystic River.....	3,012.06
Inspections.....	1,824.79
Service Pipes and Meters.....	122,859.40
Hydrants, Somerville and Medford.....	2,653.08
Somerville distribution.....	2,492.10
Dwelling house for Engineer.....	4,871.02
Chelsea Extension.....	37,347.86
Medford do.....	3,997.41
Drinking Fountains.....	1,415.05
Engine House Extension.....	22,593.08
New lines Supply Mains.....	202,905.40
New Force Main.....	7,678.02
Stable and Pipe yard.....	8,964.64
Total.....	\$1,356,175.15

The aggregate amount of Water rates received to January 1st, 1872, amounted to \$658,628.10

TABLE OF RECEIPTS, EXPENDITURES, ETC.

YEAR.	COST OF MAIN- TENANCE.		Aggregate cost of Con- struction.	Amt of out- standing water bonds	Sinking Fund.	Water rates collected	REMARKS.
	Works.	Pump- ing.					
Ending							
Dec. 31st, 1871..	19,276.95	25,592.90	1,356,175.15				
" " 1872..	25,038.04	32,344.25	1,460,000.00	1,364,000	59,157.92	860,586.70	Total to date.
" " 1873..	47,025.31	47,864.76	"	1,403,000	68,770.56	217,817.45	
" " 1874..	49,346.94	35,207.22	"		96,620.64	235,030.97	
May 1 4 mos 1875	26,408.60	13,614.97	"	1,280,000	138,228.76	147,404.59	
" 1st, 1876..	78,824.70	34,799.07	"	1,113,000	45,616.62	238,691.53	
" " 1867..	56,222.52	31,935.34	"	1,228,000†	96,701.18	289,819.11	Includ'g. amt borrowed for Mystic sewer

The amount in the above table under the head of cost of maintenance of works includes all repairs, extensions and services.

OFFICERS MYSTIC WATER DEPARTMENT.

Water Registrar; Joseph H. Caldwell, Charlestown.

Superintendent; Charles H. Bigelow, Charlestown.

Mr. L. R. Lymmes, of Winchester, has charge of Mystic Lake, the Conduit, Reservoir etc. The engines and pumps are under the care of Mr. B. Borns.

ADDITIONAL SUPPLY OF WATER.

The additional supply of water is to be derived from Sudbury River, a stream of moderate size which flows in the towns of Westboro, Ashland, Framingham, Wayland, Sudbury and Concord, in the state of Massachusetts; it flows in a general northeasterly direction and meets, in the town of Concord, the River Assabet. Both streams then join to form the Concord River, which flows into the Merrimac River at Lowell.

The water of the river is very fine, and the slight yellowish tinge which can generally be observed in it, as in many rivers of the same character, disappears entirely by storage; the water-shed is of such a nature that with the exception of a few cases where some care must be exercised, the water will be kept free from pollution.

The city diverts the water from Sudbury river in the town of Framingham, at a point where the available water-shed is $74\frac{3}{4}$ square miles in area. The Sudbury River rises and falls very quickly, and its water-shed being small, its flow, as might be expected, experiences some very extensive variations.

At the end of March, 1876, the flow at the city's dam was equal to 3,200 cubic feet per second; it is sometimes below 10 cubic feet per second in the dryest times of the summer and autumn. The river has, for a few years, yielded a rather large percentage of the rain-fall, but the calculations for the supply of the city are based upon an annual yield, in a dry year, of a quantity of water corresponding to a depth of 12 inches on the whole water-shed.

From the great variation in the flow of the river, it is obvious that large storage reservoirs must be formed above the point where the water is diverted, in order to keep an uniform supply throughout the year.

It has been calculated that seven reservoirs would be necessary, with a capacity of 4,900,000,000 gallons, to give to the city, in the dryest year, a permanent supply of 40,000,000 gallons per day.

Such an amount of water not being required at present, three reservoirs only, of a capacity of 2,000,000,000 gallons, are being constructed, which will be sufficient to secure to the city, in the dryest weather, a supply of 20,000,000 gallons per day.

The city does not take the whole river; it is bound by its charter to let 1,500,000 gallons of water, at least, flow in the bed of the river below its dams, every day in the year, for the benefit of the mill owners and riparian proprietors.

From the lower reservoir on the river the water is to be conducted through a brick aqueduct into Farm Pond, a natural pond of 200 acres, which will be used as a settling reservoir.

From Farm Pond the water is drawn into the main conduit, 16 miles long, which carries it, through the towns of Framingham, Sherborn, Natick, Needham and Newton into Chestnut Hill Reservoir.

Chestnut Hill Reservoir, already described, receives the present supply from Lake Cochituate, and is connected with the pipe distribution of the city.

The general arrangement of the water system will be better understood from the map.

The various parts of the work on the "Additional Supply" are either finished or in course of construction, and the water of Sudbury river can already be sent directly to the city.

RESERVOIRS AND DAMS.

The three Reservoirs which are now being built are very near one another; the lowest, reservoir No. 1, is situated below the confluence of Sudbury River and of Stony Brook, its principal tributary; the dams, Nos. 2 and 3, forming the other two basins, are some 4,800 feet and 5,200 feet, respectively, above the lowest, each on one of the confluent streams, thus forming an uninterrupted triangular chain of reservoirs; the lowest reservoir, where it meets the upper dams, is about 8 feet in depth.

The proximity of the three dams has enabled the city to lay, at a reasonable cost, a 48 inch iron pipe, connecting the three dams together; by its means and by an elaborate arrangement of chambers in the gate-house of the lowest dam, the water of each of the two principal streams can be sent to the city *separately*, and if any of the upper reservoirs must be emptied for cleaning or other purposes, its contents can be sent directly into the river below, without interfering with the city's supply, which would, in the same time, be maintained from the other branch through the lowest reservoir; any one who is familiar with the vegetable formations which, sometimes for a number of days, impair the purity and taste of water, will see that the arrangement above described may be found of a great practical value. At such times of the year as the use of the pipes would be resorted to, it is most probable that the whole flow of either branch of the river could be controlled in that way.

In the reservoirs proper, the usual work of cleaning and excavating where the water would be shallow or the bottom objectionable, is going on, but no work is required the description of which would be found of any particular interest.

The work on the dams is of a different character; the valleys are almost uniformly formed of strata of sand and gravel which extend sometimes to a great depth; below these strata is found some micaceous slate, sometimes quartzite and some granite, or rather syenite, of which there are large outcroppings in the neighborhood.

Numerous soundings were made to determine the position of the dams;

but in some cases the strata of gravel and sand were so much broken that the results of the soundings were but partially reliable, and new ones were wanted as the construction was going on.

The embankments, which are built across the valleys, on each side of the waste overfall, are extensive, and there being no clay in the neighborhood, within a reasonable distance, it was decided to build a centre wall laid in cement throughout their entire length; an abundance of excellent rubble stone is found on the spot.

The embankments themselves are formed of such materials as could be found in the excavations and in the immediate neighborhood, the up stream side being composed of a mixture, carefully made, of very fine compact sand, gravel, and a little loam laid in small layers well wetted and rolled; the down stream slope is formed of good gravel of all sizes laid in the same manner.

Dam No. 1, the lowest in the valley, is built in generally pervious ground composed of irregular strata of various sands and gravels; under them, at a distance varying from 30 feet to 65 feet below the bed of the river, is some micaceous slate; a continuous stratum was found, however, at a depth of 15 to 20 feet below the bed of the river, composed of very compact material, partly gravel and partly sand, and the masonry foundation of the dam was built into that compact bed.

The part of the dam forming the waste overfall is built entirely of masonry to the bottom of the foundation with a uniform width of 11 feet, capped with a crest of heavy cut stone; the centre walls of masonry contained in the earth embankments, 6 feet to 8 feet in width at the bottom, are connected directly with the masonry of the rollway, thus forming together, across the valley, a continuous water-tight screen.

A heavy apron of block stones, from 2 feet to 4 feet deep, supported partly on masonry and partly on timber, extends far below the dam, as shown on the section Pl. 4, and the overflow as well as the wing-walls are faced with coursed granite.

A gate chamber connected with dam No. 1 contains three iron flood gates, each 4 feet by 6 feet, with brass facings to secure perfect tightness.

It contains also two sets of 2 gates, each $4\frac{1}{2}$ feet by 4 feet, for the purpose of regulating the flow of the water of the reservoir into the conduit; the second set to be used in case of accident or repairs.

Two more gates have been provided for the purpose of directing either into the conduit or into the river below the dam the flow of the 48-inch pipe connected with the other reservoirs and already described. In this chamber will be put up several apparatus for measuring the flow of the river and for delivering the amount of water which must flow at all times in the bed of the stream.

The head of water behind dam No. 1 will generally be 14 to 15 feet; it will be reduced to 7 or 8 feet in case of a freshet.

The length of the rollway is 169 feet, and the total length of the dam,

embankments included, 790 feet. Dam No. 1 is now complete, with the exception of the fitting of the gates and of the house which is to cover the gate-chamber; the reservoir formed by this dam contains 230,000,000 gallons.

Dam No. 2, across the valley of the main stream, forms reservoir No. 2, which extends over two miles to the town of Ashland.

The dam is built with a long waste overfall, in order to avoid extensive fluctuations above the ordinary water line; the general formation of the valley is characterized by deep beds of very fine sand with a small and irregular crust of gravel near the surface, which is covered with loam; in sounding, however, rock was discovered at a point of the valley where the hills on each side are steeper and more extensive than elsewhere, and it was found that there existed an extensive back bone extending across the valley far enough up and down stream to make an excellent foundation; near the hills, however, the surface of the rock was found to have a downward inclination. On that rock the structure is founded.

The general plan of the dam is the same as for Dam No. 1, there being in the middle a masonry overflow and apron, and, on each side, earth embankments with a wall of masonry in their centres.

The upper portion of the ground having been removed, it was found that the rock was quartzite, the top of which was full of detached pieces, sometimes very large, presenting deep seams; they were removed with some trouble, and owing to these difficulties the foundation reached a depth varying from 15 feet to 25 feet below the level of the stream.

On the east side of the foundation granite was found instead of quartzite, and it was used for building the foundation of the gate house.

Owing to the fact that the surface of the rock had an inclination downward as it reached the hills on each side, the foundations of the embankment walls were carried on upon the rock bottom, until they were produced to a safe distance into the hills, when the walls were gradually stepped off into the adjoining ground formed of compact sand; care was taken, however, to build the walls on this more yielding foundation to a great height without connecting them with the wall previously built on rock; after a sufficient time the walls were connected, and they never showed the slightest sign of unequal settlement.

The middle portion of the dam or waste overfall, 182 feet long, which is built exclusively of masonry, is 16 feet wide and extends to the rock below; this part of the dam and the wing walls are faced with coursed granite. A heavy stone apron similar to that at Dam No. 1 and shown on the section (plate 4), extends far below.

A gate chamber is connected with this dam and contains 7 gates of a general size of 4 feet by 5 feet, for the purpose of drawing water at various elevations from the Reservoirs, and of regulating the flow through the 48-inch pipe already described.

The total length of this dam, including embankments, is 1325 feet.

All the foundations are now built to the surface of the ground; the superstructure is to be built this season.

The surface of the lower Reservoir being much above the surface of the valley where this dam is built, there will be generally little head against it; if Reservoir No. 1 was empty the head of water would be about 18 feet.

The contents of the reservoir are 500,000,000 gallons.

The third Dam (forming Reservoir No. 3) is built across the valley of the other stream. The soundings, in that valley, showed an almost uniform section of loam and gravel for an inconsiderable depth, underlaid with fine sand to a depth of over 60 feet; the soundings did not extend beyond that depth.

The sand in which the greatest part of the foundation is built is extremely fine and, when confined, impervious and compact.

The Dam is formed, as are the others, of a central part built of masonry and comprising the rollway and the gate house, and of embankments reaching the upper parts of the valley.

An extensive trench was first opened across the valley, supported by sheet piling until it was well within the side hills. When it reached a depth of 13 feet below the bed of the stream a line of sheet piling 8 inches by 8 inches was driven on the upstream side of it, to a depth varying from 12 feet to 14 feet; great care was taken, in driving, to secure perfect water-tightness. The piles were tongued and grooved; the sand was so compact that, after a penetration of 6 feet or 7 feet, the piles could not advance, at each blow, more than $\frac{1}{4}$ inch.

These piles were sawed at a height of 6 to 7 feet above the bottom of the trench. In this trench, the bottom of which was 13 feet below the bottom of the stream, was then built, close to the row of piles, as shown by the section, the masonry forming the central part of the Dam, 18 feet thick, and the beginning of the centre walls of the embankments, 8 feet thick.

At a safe distance, in both side hills, the sheet piling was omitted and the centre wall was continued with a reduced width to a sufficient depth for securing a good compact bottom; in the southern hill-side, however, the gravel was so loose that the excavation for the centre wall was carried down to a great depth into a better material; at one point the bottom of the foundation of the centre wall is 40 feet below the natural surface.

The rollway, wing walls and chamber are faced in granite.

The gate chamber contains nine large gates for regulating the flow of water into the lower Reservoir and for the necessary connection with the 48-inch pipe.

The rollway is 100 feet in length and the total length of the dam including all the embankments is 3,000 feet.

The head of water, which ordinarily will be 16 feet, will be increased to about 26 feet when the lower reservoir is empty. The capacity of this reservoir is 1,147 million gallons.

The foundations to the surface of the ground and a large proportion of the embankments are already done and the masonry forming the central part of the dam will be built this year.

FROM THE LOWER RESERVOIR TO THE MAIN CONDUIT.

Coming back to the gate house of the Lower Dam, (No. 1) we find in it the head of the conduit which will convey the waters of the river in to Farm Pond and which is nearly completed.

This conduit is built in low ground with an inclination of two feet in one mile and is about 4,000 feet long. Its dimensions (see section plate 4) are somewhat smaller than those of the main conduit on account of its greater fall, but it is constructed in the same manner with a concrete foundation, stone side-walls with a high arch and the few remarks that will be made about the construction of the main conduit will apply to this. Near Dam No. 1, where it is close to the river, this structure is protected from it by heavily paved slopes.

Farm Pond, into which this conduit empties, is a natural sheet of water about 200 acres in area, and draining a very small water-shed (about one square mile). Its waters are very pure and it forms a good settling basin for the waters of the Sudbury River; the distance between the outlet of the small conduit mentioned above and the head of the main conduit is about one mile.

No objectionable flow will be allowed to pollute the waters of this pond, the shores of which will be protected by a complete system of drainage.

The available capacity of Farm Pond is 155 million gallons.

CONDUIT.

At the southeast corner of Farm Pond is placed the gate chamber, which contains the head of the main conduit. It is provided with two sets of large sluice gates 4x6 ft. Its foundation is on piles, as is the foundation of the beginning of the conduit in Farm Pond, and the material found at the bottom for a considerable depth being sand, it has been found preferable not to remove the heavy coffer-dam which had been used for construction, but to retain it in place except around the gate house where it had to be sawed off to a considerable depth under water.

After leaving Farm Pond, the general direction of the conduit for about 5 miles is southeasterly, thence for about 9 miles northeasterly, and thence to Chestnut Hill reservoir easterly. Its total length is about 16 miles. The first mile of its course passes through the town of Framingham; the next $2\frac{3}{4}$ miles through Sherborn; then 3 miles through Natick, $5\frac{1}{3}$ miles through Needham and some $3\frac{3}{4}$ miles through the City of Newton to the gate-house at the reservoir, which is very near the boundary line between Newton and Boston.

At the shore of Farm Pond the conduit passes under the Boston and Albany Railroad.

For convenience of description, reference will be made to the stations on the line enumerated in the following table. Stations are 100 feet in length.

SECTION.	STATION.	TO STATION.	TOTAL LENGTH FEET.
1	0	6	600
2	6	51 + 50	4,550 ✓
3	51 + 50	114 + 50	6,300
4	114 + 50	155 + 70	4,120
5	155 + 70	190	3,430
6	190	229	3,900
7	229	284 + 25	5,525
8	284 + 25	315 + 55	3,130
9	315 + 55	381	6,545
10	381	388	700
11	388	432	4,400
12	432	509	7,700
13	509	551 + 50	5,250
14	551 + 50	623	6,150
15	623	639	1,600
16	639	684	4,500
17	684	730	4,600
18	730	737	700
19	737	773 + 22	3,622
20	773 + 22	to end.	about one mile.

Total length about 16 miles.

The crossing of the Boston and Albany Railroad is from 3 + 60 to 5 + 25. The Milford Branch of the Boston and Albany Railroad is crossed at 11 + 25 and the Framington and Mansfield Railroad on section 3 at 66 + 50. These are all the railroads the line encounters. On section 2, station 34 + 67, Beaver Dam Brook, the chief feeder of Lake Cochituate passes under the conduit by a large siphon culvert, necessitated by the water level of the conduit and brook being so nearly alike.

This is a prominent feature of the first sections, that the water-level between the brooks and conduit being so nearly the same, the crossings are made by inverted siphons. This is advantageous with regard to the highways, as the grades did not require raising.

On sections 2, 3 and 4 the excavation was principally sand and quicksand entailing more or less pumping and sheet piling, etc.

On section 2, two soft peat-holes or pockets were encountered, one of which, at station 17, was 200 feet in length. In this the peat extended to a few feet below grade, but the other at station 25, of the same length, was several feet deeper. In both cases the peat was entirely removed, and the holes filled with gravel to a width sufficient to allow of the entire embankment to rest on a solid foundation.

At station 112, the line crosses Course brook, another feeder of Lake Cochituate. At this point a waste-weir is constructed, to empty the conduit if necessary, and from which the waste water finds its way into the lake.

The first 4 sections pass through open farming country. At section 5 the line passes through the Sherborn swamp, whose surface is about 2 feet above the bottom of the conduit. There the peat was removed from 5 to 15 feet in depth, its place filled with well rolled gravel and it was left to solidify through the winter—no sheeting was necessary.

On section 4 occurs the first rock cutting of any importance. It is about six hundred feet long, with a maximum depth of 10 feet.

The first tunnel was bored on section 6, through one of the ridge making out from the Charles River. It is 1760 feet long.

Section 7 is built entirely through woods and swamps. A peat excavation some 550 feet long was made, the same course being pursued as before. Its greatest depth was 15 ft. No sheeting was required. In general the material to be excavated was gravel and hard-pan.

On section 7, station 271 + 40, the second waste weir was built. This brook empties into the Charles River.

Section 8 includes the Badger Hill Tunnel, 1,575 feet long. Section 9 passes close to the banks of Charles River. The excavation is all gravel. The level of the water in the conduit is some 40 feet higher than that of the river. Should the consumption of the city demand it, the river water can be here drawn upon by pumping it into the conduit.

Section 10 is the Waban Brook bridge. (Plate 5). The bridge is formed of 9 semi-circular arches, 44 ft. 8 in. span, built of Maine granite with a brick parapet and iron railing. The bridge is 536 feet long. The valley is about 40 ft. deep and 2,000 feet long. The line as located, passes through a small knoll, and the conduit is carried over the remaining portion of the valley in an embankment, in section 11, thirty feet high and 1,200 ft. long. The excavation on section 11 is largely in hard-pan and rock. A cut in this section was at its deepest 35 feet, while 600 feet of it was 15 feet deep.

Excavation on section 12 is gravel with boulders and some ledge. In this section Fuller's waste weir is constructed, and a long cut of about a mile in length, extending into section 13 was excavated. Some half mile of this cut was in wet quicksand, the rest gravel.

On section 13 is the Alms-house embankment, 30 feet in the deepest and some 700 feet long. Not far to the east of this bank comes the Rosemary brook siphon; the valley, crossed in its narrowest point is about 1,800 feet wide. It is to be crossed by 3 lines of 48 in. pipe, two of which only are at present laid. The channel of the brook is covered by an arch culvert 10 ft. diameter and the pipes are here furnished with blow-offs. Substantial masonry structures will form the siphon chambers. The water surface of Rosemary brook is 55 feet below the grade of the conduit.

On section 14 there is a cut about half a mile long, and an embankment with a maximum depth of 50 feet.

Section 15 comprises principally the Charles River bridge 11.8 miles from Farm Pond, and most important structure on the line. Its length is 475 feet between the chambers at the ends of the bridge. At the westerly end is an arch of thirty-seven feet space, then comes the long span arch, which crosses the river. This arch is 130 feet span, is segmental, and has a radius of 69 feet. The thrust is taken directly by rock foundations on both sides. There are 4 semi-circular arches of 37 ft. span, and a flat arch of 28 ft. span, over a town road, on the east side of the river. The piers, arches and

abutments up to the level of the conduit are built of granite ; above this, the parapet is of face bricks in panels, with a heavy granite coping; the whole surmounted by an iron railway. Plate (5).

Section 16 is partly in embankment and partly excavation. The material is gravel, and the country undulating and thickly settled.

One rock cutting was made in this length.

Section 17 is all gravel excavation.

Section 18 is a tunnel in gravel.

Section 19 is all sand and gravel excavation with one exception. Waste-weir No. 4, emptying into Hammond's brook is located at Station 738 + 20.

Section 20 is the Beacon street Tunnel.

The section adopted for the conduit is shown on Plate 4. It is equivalent to a circular section of $8\frac{1}{2}$ feet in diameter and in ordinary conditions of cleanliness will deliver at the rate of 70 million gallons in 24 hours, when flowing at the assumed water line.

The section is of stronger form than is usually given; it is designed to have sufficient stability to resist the lateral thrust of the contained water and the arch. Throughout the whole length of the conduit, man-holes are provided, about 1500 feet apart; some of these are of such a form as to permit of their use as gauging chambers, in which to measure the flow of the water, or other experiments.

The arch and interior lining are of brick, and the side walls of rubble stone masonry.

WASTE WEIRS.

No. 1.	Course brook.	Station	112
" 2.	Beacon "	"	271 + 40
" 3.	Fuller's "	"	459
" 4.	Hammonds "	"	738 + 15

BLOW-OFFS.

Rosemary brook. Station 553.

TOWN LINES.

Framingham	and Sherborn	Station,	45 + 72.
Sherborn	" Natick,	"	191 + 68.
Natick	" Needham,	"	350.
Needham	" Newton,	"	633 + 50.
Newton	" Boston,	"	82.824

DRAINAGE AREAS OF STREAMS CROSSED.

Beaver-Dam brook	3,195 acres.
Course "	1,343 "
Sawens "	768 "
Bacon's "	977 "
Waban "	12 square miles.
Rosemary "	1,610 acres.
Charles River "	200 square miles.

It has already been remarked that the section of the Conduit has been made very strong. Being built in materials of all sorts, from rock and hard gravel to the most treacherous quicksand and in all positions from deep trenches to artificial banks and bridges, the structure has not an uniform exterior outline, but the interior shape is uniform throughout.

It may be seen from the sections of the Conduit, Plate 4, that it is a structure which requires an unyielding foundation and much care has been bestowed on the preparation of it.

In wet sandy trenches which occurred frequently on the first few miles of the line, a wooden platform has been used as a support for the Conduit, (See Plate 4), and the drainage has been so constructed that no settlement could occur during construction.

In peaty meadows the soft material has been removed for nearly the whole width of the embankment and replaced by compact gravel which although laid in water and in thin layers, was left to settle a whole winter before any building was allowed to take place on it.

In several places along the line, embankments have been formed on solid ground to support the Conduit at various elevations. These embankments have been made in some cases of very compact gravel, in other cases of coarse sand and fine gravel and of ordinary gravel of all sizes.

All of the embankments were built in the manner already described, in thin layers wetted and rolled, and were allowed to stand a whole winter, sometimes two, before building upon them.

None of them showed any settlement, except one very extensive embankment, made of gravel of no great compactness, and which had been purposely overloaded. In this case a slight settlement took place as was expected; for a distance of several hundred feet this embankment is fifty feet in height. The Conduit is now built upon it and has not shown any signs of settlement.

In another case where the materials used were more compact, the levels rather showed a slight swelling of the embankment.

The shape of the concrete foundation of the Conduit has generally been changed on the heaviest embankments, its section being deeper in the centre than on the sides, in shape of a wedge.

The section of the Conduit on the two large bridges is different, (See Plate 5) and the inside surface is protected by a coat of Portland cement mortar; a space has been left in the side walls to intercept any water which might percolate through them; that water then flows into some longitudinal drains, shown in the longitudinal section of Waban Bridge, Plate 5, and goes out by some openings made for the purpose; these drains can also be used as passages to visit the under part of the Conduit throughout the bridges.

In several portions of the line, where the conduit is very heavily loaded the whole arch is 12 in. thick; its thickness has been increased to 16 in. in places where it is within a few feet of railroad tracks.

It may be remembered that mention has been made of several tunnels built along the line of the conduit; a section is shown on plate 4.

The first of these tunnels (Section 6) runs through a granite formation and through several varieties of chloritic shist; a large portion of the latter rock seems, at first, sound enough to stand without arching; it was however found afterwards that the rock was formed of small fragments, the joints of which were filled with a green chloritic cement which soon lost its cohesion by the changes caused by the opening of the tunnel and it was found necessary to arch the whole of it, 1760 ft. in length.

The second tunnel, 1575 ft. long, runs through a granite foundation; the rock is so disintegrated for half of its length that it has been supported by brick arching.

The third tunnel, section 18, 100 ft. in rock and 400 ft. in fine gravel and sand, was excavated with difficulty, the line passing through valuable property and very near the surface; it required the closest attention to avoid caving.

The fourth tunnels (Section 20) is 4635 ft. long and runs through conglomerate and slate. The compactness of the rock is such that 200 ft. only of the whole length has required arching.

The construction of this tunnel was prosecuted from four faces, two of which ran from a shaft, some sixty feet in depth, sunk in a valley and near the centre of the tunnel.

Most of the work was done by compressed air.

The work commenced in September 1873, and was finished and accepted in December, 1875.

The other tunnels were all worked by hand labor.

Giant powder was the explosive almost exclusively used for the four tunnels.

In order to secure through the tunnels a smooth bottom without interfering with the free percolation of water into them, a layer of loose broken stone has been deposited on the rock bottom and over it has been laid a thin concrete floor through which weepers are provided to let the water circulate freely without any danger of lifting the floor.

The conduit terminates in a large chamber located at Chestnut Hill Reservoir, from that chamber the water from Sudbury River is distributed as follows, each pipe being provided with a sluice gate:

One 48 in. pipe is connected with one of the divisions of Chestnut Hill reservoir.

One 60 in. pipe is connected with the other division of Chesnut Hill reservoir.

One 48 in. pipe with the Cochituate Aqueduct. Another 48 in. pipe is laid around Chestnut Hill reservoir and is connected, independently from it, with the city pipes.

Room has also been provided for a duplicate of this pipe which will be laid when the increase in the consumption of water will render it necessary.

TABLE No. 1.

Annual Amount of Rainfall, in Inches, at Lake Cochituate, Boston and vicinity, 1849 to 1875, inclusive.

YEAR.	PLACES AND OBSERVERS.						
	Lake Cochituate, by Sup't Western Division, B.W.W.	Boston, by J. P. Hall, to 1865, by W. H. Bradley since 1865.	Cambridge, by the Director of the Observatory.	Waltham, by Agent Boston Manufacturing Company.	Lowell, by Merrimac Manufacturing Company.	Lowell, by Locks and Canals Company, J. B. Francis.	Providence, by A. Caswell.
1849.....	..	40.30	40.97	40.74	41.91	..	34.69
1850.....	..	53.93	54.07	62.13	51.09	..	51.49
1851.....	..	44.31	41.97	41.00	45.63	..	43.33
1852.....	47.93	47.94	40.51	42.24	42.78	..	38.58
1853.....	55.73	48.86	53.83	45.04	43.92	..	53.27
1854.....	43.15	45.71	45.17	41.29	42.08	..	46.25
1855.....	34.96	44.19	47.59	40.63	44.89	48.41	39.05
1856.....	40.80	52.16	53.79	42.33	42.49	45.97	40.97
1857.....	63.10	56.87	57.92	44.04	49.38	52.02	44.75
1858.....	48.66	52.67	45.46	37.40	37.73	35.80	44.51
1859.....	49.02	56.70	..	48.49	47.51	48.41	45.16
1860.....	55.44	51.46	46.95	45.97	46.91	46.67	38.44
1861.....	45.44	50.07	50.14	36.51	43.32	42.95	44.25
1862.....	49.69	61.06	57.21	46.42	44.26	44.61	50.14
1863.....	69.30	67.72	56.42	53.66	52.37	57.81	55.17
1864.....	42.60	49.30	39.46	36.56	38.11	40.64	36.83
1865.....	49.46	47.83	43.59	35.84	37.38	38.82	44.69
1866.....	62.32	50.70	..	43.46	38.18	41.36	46.02
1867.....	56.25	55.64	41.71	41.40	45.54	45.87	47.04
1868.....	49.71	64.11	39.89	44.65	47.96	49.58	53.52
1869....	64.34	66.28	47.98	47.30	47.30	48.96	47.70
1870.....	55.89	59.73	41.53	39.40	46.30	48.71	49.02
1871.....	45.39	48.33	40.56	36.82	44.45	44.17	47.91
1872.....	48.47	58.04	52.73	45.80	44.32	48.67	48.71
1873.....	45.43	54.94	46.81	42.58	39.86	45.05	52.56
1874.....	35.93	41.09	38.73	32.32	35.68	41.75	43.39
1875.....	45.49	51.01	51.00	40.30	40.29	43.63	52.22

TABLE No. II.

Statement showing amount of Rainfall on Water-shed of Lake Cochituate, amount of Water consumed and wasted, available amount Received into Lake, available percentage of Rainfall, etc., from 1852 to 1875, inclusive. Water-shed of Lake = 12,077. acres.

YEAR	Rain-fall.	Amount of rain-fall on Water-shed of Lake Cochituate.	Amount of Water drawn from Lake	Amount of Water wasted from Lake.	Total amount consumed and wasted.	Rise of Lake during the year.	Fall of Lake during the year.	Total amount of Rainfall received into Lake.	Daily average amount of rainfall received into Lake.	Percentage of Rainfall received into Lake.
	Inches.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	
1852*	47.93	15,759,207,000	2,974,042,800	4,020,566,885	6,994,609,685	.....	2613,000,000	6,733,249,685	18,396,887	43 per cent.
1853	55.73	18,366,561,000	3,167,939,500	3,166,417,500	6,334,357,000	239,580,000	.....	6,523,937,000	17,873,800	35 per cent.
1854	43.15	14,187,562,000	3,614,230,000	4,187,733,020	7,801,993,020	.....	217,800,000	7,584,163,020	20,778,529	53 per cent.
1855	34.00	11,494,719,000	3,776,399,500	No acct. kept.	.....	.....	326,700,000	.....	.....	.....
1856	40.80	13,414,822,000	4,409,787,600	No acct. kept.	.....	598,959,000	.....	.....	.....	.....
1857	63.10	20,747,052,000	4,644,970,000	10,625,900,000	15,270,890,000	32,670,000	.....	15,393,500,000	41,927,562	74 per cent.
1858	48.66	15,999,234,000	4,680,155,000	1,934,590,000	6,623,655,000	.....	141,570,000	6,482,085,000	17,759,013	40 per cent.
1859†	49.02	16,117,602,000	4,808,373,000	7,550,000,000	12,377,875,000	283,140,000	.....	12,661,015,000	34,687,712	78 per cent.
1860	55.44	18,228,471,000	6,309,108,000	None.	6,309,108,000	174,240,000	.....	6,483,348,000	17,714,095	35 per cent.
1861	45.44	15,269,303,000	6,039,095,900	3,377,558,966	10,016,654,866	.....	1,459,260,000	8,557,394,866	23,444,917	56 per cent.
1862	49.66	16,337,890,000	6,659,000,000	33,200,000	6,692,200,000	1,300,800,000	.....	7,399,000,000	20,271,233	45 per cent.
1863	69.30	22,735,536,000	5,927,952,500	2,105,696,470	8,034,648,970	702,300,000	.....	8,555,045,970	24,260,408	39 per cent.
1864	42.60	14,006,726,000	6,105,366,700	1,368,746,000	7,474,052,700	.....	1,848,577,000	5,625,475,700	15,370,152	40 per cent.
1865	49.46	16,262,265,000	4,621,630,000	1,688,120,674	6,309,750,674	743,242,500	.....	7,052,993,174	19,323,270	43 per cent.
1866	20.40	20,490,455,000	4,463,855,000	None.	4,463,855,000	.....	.....	5,206,827,500	14,205,286	25 per cent.
1867	56.25	18,494,795,000	4,951,225,000	2,482,041,000	7,433,266,000	.....	698,811,000	6,734,455,000	18,450,600	36 per cent.
1868	49.71	16,450,544,000	5,405,515,000	2,597,684,000	7,913,199,000	349,371,000	.....	8,259,570,000	22,567,160	50 per cent.
1869	64.14	21,090,808,000	5,500,606,000	1,635,570,000	7,139,321,000	430,882,000	.....	7,620,203,000	20,877,300	36 per cent.
1870	55.59	18,328,694,000	5,423,500,000	4,818,971,000	10,266,781,000	.....	1,736,085,000	8,505,690,000	23,453,000	47 per cent.
1871	48.39	14,855,304,000	5,775,151,200	None.	5,775,151,200	.....	259,933,000	4,972,507,000	13,623,470	33 per cent.
1872	45.43	14,808,419,000	6,511,826,900	.....	9,429,803,900	.....	.....	5,042,480,300	15,416,610	35 per cent.
1873	45.43	14,808,419,000	6,511,826,900	.....	9,429,803,900	.....	.....	5,914,671,900	24,423,760	60 per cent.
1874	35.93	11,752,697,000	6,623,972,900	1,145,581,700	7,769,554,600	.....	.....	6,402,109,600	17,576,030	54 per cent.
1875	45.49	14,918,006,000	8,709,955,500	None.	8,709,955,500	\$1,222,882,000	.....	5,700,040,500	15,786,930	39 per cent.
Average 50.19		Average daily waste for 22 years.....	6,925,390			Average daily yield of Lake water-shed for 22 years, 20,827,570.				45 per cent.
		" " " 6 "	52-59.14,378,000							
		" " " last 16 years, '60-75.	4,130,975							

*Observation of rainfall at Lake Cochituate commenced 1852, and these observations are assumed as correct for the whole district.

†Lake raised two feet.

‡Amount received from Sudbury river in 1872, 1,676,666,400 gallons.
 " " " 1875, 2,555,800,000 "

TABLE No. III.—*Heights and Distances.*

High water mark, Lake Cochituate, - - -	134.36	feet.
Bottom of interior of Cochituate Aqueduct at Lake Cochituate, - - -	121.03	"
Bottom of interior of Cochituate Aqueduct at West Pipe Chamber, - - -	119.04	"
Bottom of interior of Cochituate Aqueduct at East Pipe Chamber, - - -	118.52	"
Bottom of interior of Cochituate Aqueduct at Brookline Reservoir, - - -	116.77	"
Top of dam of Brookline Reservoir, - - -	126.60	"
High water mark, Brookline Reservoir, - - -	124.60	"
Top of dam of Chestnut Hill Reservoir, - - -	128.00	"
High water mark, Chestnut Hill Reservoir, - - -	125.00	"
High water mark, Parker Hill Reservoir, - - -	219.00	"
Lower floor of Gate House, Parker Hill Reservoir, - - -	197.00	"
Top of Stand pipe, - - -	238.88	"
Bottom of interior of Sudbury River Conduit at Farm Pond, - - -	141.35	"
Bottom of interior of Sudbury River Conduit at West Siphon Chamber, - - -	131.09	"
Bottom of interior of Sudbury River Conduit at East Siphon Chamber, - - -	129.36	"
Bottom of interior of Sudbury River Conduit at Chestnut Hill Reservoir, - - -	124.05	"
Top of masonry overflow, Dam 1, - - -	157.75	"
Top of stop planks, Dam 1, - - -	159.50	"
Top of masonry overflow, Dam 2, - - -	166.00	"
Top of masonry overflow, Dam 3, - - -	175.50	"
Bottom of interior of Supply Conduit from Dam 1 to Inlet Chamber, - - -	144.84	"
Bottom of interior of Supply Conduit at Farm Pond, - - -	143.01	"
High water mark, Mystic Lake, - - -	7.00	"
Top of Dam, Mystic Lake, - - -	11.00	"
Bottom of Mystic Conduit at Lake, - - -	— 4.17	"
Bottom of Mystic Conduit at Pipe Chamber, - - -	— 4.92	"
Bottom of pump well, Mystic Engine House, - - -	— 11.00	"
Bottom of Mystic Reservoir, - - -	125.00	"
High water mark, Mystic Reservoir, - - -	147.00	"

DISTANCES ON SUDBURY RIVER WORKS.

Gate Chamber at Dam 1 to Inlet Chamber at Farm Pond, -	4170	"
Gate Chamber at Farm Pond to West Siphon Chamber, -	54,100	"
West Siphon Chamber to East Siphon Chamber, - - -	1,800	"
East Siphon Chamber to Chestnut Hill Reservoir, - - -	28,012	"

COST OF THE WORKS TO MAY 1, 1876.

Cost of Water Works to January 1, 1850, as per final report of Water Commissioners.....	\$3,993,051	83
Extension to East Boston.....	231,065	44
Jamaica-pond aqueduct.....	45,237	50
New dam at Lake Cochituate.....	10,940	03
Raising lake two feet, including damages.....	28,002	18
Dudley pond, lower dam, and making connections with the lake...	13,932	23
New main from Brookline reservoir.....	304,991	83
Land and water rights since January 1, 1850.....	58,331	40
Land damages since January 1, 1850.....	15,511	62
New pipe-yard and repair shop.....	25,666	51

Upper yard, buildings, etc.....	9,165	63
New water-pipes, East Boston,.....	20,999	43
New main, East Boston.....	24,878	08
Water to Deer Island.....	75,000	00
Pumping-Works at Lake Cochituate.....	15,000	00
High service, stand-pipe, engine-houses and engines.....	83,829	53
High service, South Boston.....	27,860	29
Chestnut-Hill reservoir, including land.....	2,449,982	07
Parker-Hill reservoir, including land.....	228,246	17
Charles River siphon.....	26,532	35
Additional supply of water, including land damages and all expenses	1,186,254	56
Cost of main pipe, since January 1, 1850.....	830,310	98
Cost of laying main pipe, since January 1, 1850.....	454,233	70
Cost of hydrants, stopcocks, and boxes, and setting the same.....	251,376	63
Cost of main pipe, for extension in Roxbury, Dorchester, Brighton and West Roxbury districts.....	877,197	81
Cost of laying main pipe for extension in Roxbury, Dorchester, Brighton and West Roxbury districts.....	358,429	04
Cost of hydrants, stopcocks and boxes, and setting same in above districts.....	344,859	74
	\$12,050.936	63
Cr. By sale of Jamaica-pond aqueduct,	\$32,000	00
By sale of land to May 1, 1876,	24,356	85
	56.356	85
	\$11,994.579	78

TABLE OF ERRATA.

- Page 4 on 16th line from bottom, for "or granite" read "of granite."
Page 9 on 12th line from bottom, for "ventilaton" read "ventilator."
Page 17 on 23d line from bottom, for "three 15 in." read "three 16 in."
Page 22 on 8th line from bottom, for "leaded points" read "leaded joints."
Page 27 on 18th line from bottom, for "rarely ample" read "barely ample."
Page 30 on 23d line from bottom, for "increased duty" read "increased supply."
Page 34 on 42d line from bottom, for "were drawn" read "were driven."
Page 34 on 27th line from bottom for "six wastepumps of six feet each" read "six waste openings of nine feet each."
Page 24 on 24th line from bottom, omit: "It increases in width as it descends."
The sides of the fish-way are *parallel*.
Page 35 on 30th line from bottom, for "leak" read "lake."
Page 35 on 15th line from bottom, for "screws" read "screens."
Page 83 on 5th line from bottom, for "120 ft. long" read "160 feet long."
Page 39 on 17th line from bottom, for "30 ft. 0 in. long" read "50 ft. 0 in. long."
Page 39 11th line from bottom, for "side wells" read "side walls."
" 40 on 5th line from top, omit: "and one on the main in advance, etc., to period.
Page 40 on 9th line from bottom, for "gravel path" read "concrete path."
" 41 on 18th line from bottom for "pipes or" read "pipes of."
" 47 on last line of table of receipts, etc., for year "1867" read "1877."
" 47 on 3d line from bottom, for "L. R. Lymmes" read "L. R. Symmes."
" 56 on 3d line from top, for "iron railway" read "iron railing."

